Surat Gas Project – Girrahween Field Compressor Station

Air Quality Impact Assessment

Arrow Energy Pty Ltd

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27 June 2023

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Basis of Report

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Arrow Energy Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

Executive Summary

SLR Consulting Pty Ltd (SLR) has been engaged by Arrow Energy (Arrow) to perform an air quality impact assessment, including a detailed air dispersion modelling study, to assess potential air quality impacts from the proposed Field Compressor Station (FCS) to be located at Girrahween in the Surat Basin, Queensland.

The proposed FCS will consist of the following main plant:

- Screw compressors (up to six), which will compress low-pressure coal seam gas (CSG)
- A hybrid power plant consisting of:
  - Thermal generation through CSG fired internal combustion engines (7 x 3.36 MW with one generator as sparing capacity)
  - Solar farm nominally sized at 15 MW_{ac}
  - Battery energy storage system (BESS) nominally sized at 7.5 MW / 3.75 MWh
- A multi-point ground flare (MPGF), to manage distressed gas
- A slug catcher to remove water in the gas line
- Filter coalescers to remove solids and liquids in the gas line

All sensitive receptors in the study area are existing dwellings/residential premises. No other sensitive receptor types were identified within the study area. All sensitive receptors are located at least two kilometres from the Girrahween FCS and all well pads are located at a distance greater than 200 metres from sensitive receptors, as per EIS commitments for the Arrow Surat Gas Project (SGP).

Meteorological and dispersion modelling was performed using a combination of the Weather Research and Forecast (WRF), CALMET and CALPUFF models to predict downwind concentrations of nitrogen dioxide (NO_2) and carbon monoxide (CO) due to emissions from the proposed power plant and major potential flaring events at this FCS.

Modelling of NO_2 and CO was also performed for air emissions associated with the small (60 kVA) CSG fired power generators to be installed at the multiwell pads to establish required minimum separation distances between well pads and nearest sensitive receptors. Two different categories of well pad power systems (consisting of four and six CSG fired generators respectively) were investigated as part of this study. Air emissions from single vertical wells with a single genset have been previously assessed. Single vertical wells with a single generator release less air emissions and a smaller separation distance is required than for multiwell pads.

All air quality modelling was conducted at maximum emission rates and maximum loads which results in a conservative assessment of potential air quality impacts.

Based on the modelling results, the following conclusions have been drawn:

- The modelling results showed that under normal maximum operating conditions (i.e. concurrent operation of seven power station generators at maximum load), the proposed Girrahween FCS operation has no potential to result in any exceedances of the relevant ambient air quality criteria at surrounding sensitive receptors.
- The modelling of NO_X and CO emissions from maximum flaring events at the proposed Girrahween FCS showed that predicted short term average NO_2 and CO concentrations would also remain well below the relevant ambient air quality guidelines.
- Modelling results for the well pad generators showed that a separation distance of 200 m between the well pad and the sensitive receptors would be adequate (for air quality constraints) for all categories of well pads (single and multiwell pads).

Based on the above, no air quality constraints have been identified for the proposed Girrahween FCS or the well pad operations, by this air quality impact assessment.

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1.0 Introduction

SLR Consulting Australia Pty Ltd (SLR) has been engaged by Arrow Energy (Arrow) to undertake an air quality impact assessment (AQIA) for the proposed Girrahween Field Compressor Stations (FCS) as part of their Surat Gas Project (SGP) in Queensland. The Girrahween FCS site is located approximately 18 km north of Miles.

1.1 Background

The Girrahween FCS will facilitate compression of low-pressure coal seam gas (CSG) and deliver medium-pressurised gas downstream to the gas sales delivery point. This FCS will consist of the following:

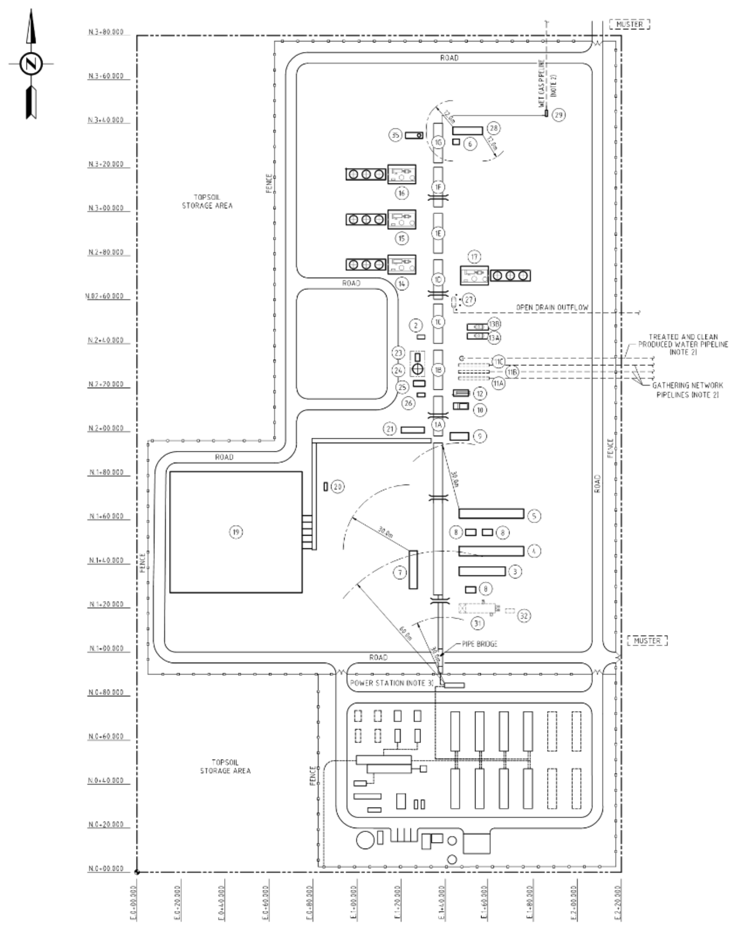
- Screw compressors (up to six) which compress the low-pressure CSG. The compressors will be powered by electricity from the on-site power plant.
- A hybrid power plant consisting of:
  - Thermal generation through CSG fired internal combustion engines (7 x 3.36 MW with one generator as sparing capacity)
  - Solar farm nominally sized at 15 MW_{ac}
  - Battery energy storage system (BESS) nominally sized at 7.5 MW / 3.75 MWh

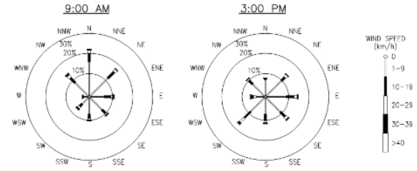
  The hybrid power plant provides power to the FCS used mainly to power the FCS compressors.
- Multi-point ground flare (MPGF) to manage distressed gas.
- Slug catcher to remove water in the gas line.
- Filter coalescers to remove solids and liquids in gas line.

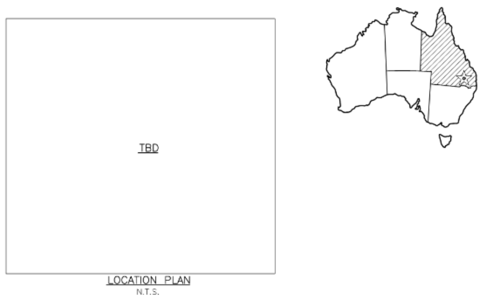
The proposed site layout of the Girrahween FCS is presented in **Figure 1**.

The Girrahween development also includes the establishment of single and multiwell pads for the extraction of CSG from coal seams. Well pads are powered by small (60 kVA) CSG fired internal combustion engines. The potential for air quality impacts from the operation of CSG well pads is also included in this assessment.

Figure 1 Site Layout – Girrahween FCS







EQUIPMENT LIST

ITEM	DESCRIPTION	SIZE (mm) (LxWxH)	PACKAGE TAG
1	PIPERACK MODULE (A-G)	18000 x 4000	-
2	LUBE OIL INJECTION PACKAGE	3500 x 1750	00-A-0011
3	BOP SWITCHROOM	21000 x 4000	-
4	COMPRESSION SWITCHROOM	29400x 4250	-
5	COMPRESSION SWITCHROOM	29400x 4250	-
6	GAS ANALYZER SKID	3048 x 2438	50-A-0002
7	HV SWITCHROOM	15000 x 3800	-
8	DISTRIBUTION TRANSFORMERS	3500 x 1750	-
9	AIR COMPRESSOR PACKAGE	8400 x 3500	40-A-0001
10	PRODUCED WATER TRANSFER AND PUMP PACKAGE	-	00-A-0004
11A/B	SLUG CATCHER #1 AND #2	-	SP-25-0001/0002
11C	SLUG CATCHER #3 (FUTURE TIE-IN)	-	SP-25-0003
12	SLUG CATCHER DRAIN SKID PACKAGE	6777 x 2929	99-A-0001
13A/B	INLET FILTER SEPARATOR PACKAGE #1 & #2	-	00-A-0001/0002
14	MAIN COMPRESSOR PACKAGE #1	-	01-A-0001
15	MAIN COMPRESSOR PACKAGE #2	-	02-A-0001
16	MAIN COMPRESSOR PACKAGE #3	-	03-A-0001
17	MAIN COMPRESSOR PACKAGE #4	-	04-A-0001
18	-	-	-
19	GROUND FLARE PACKAGE	60000 x 55000	12-A-0002
20	FLARE CONTROL SKID	3600 x 1375	-
21	FLARE KNOCKOUT DRUM PACKAGE	10500 x 2625	12-A-0001
22	-	-	-
23	TREATED WATER EXPORT PUMP	-	00-P-0002A/B
24	TREATED WATER TANK	Φ3573 x 2722	0-T-0006
25	OIL SEPARATION UNIT	5250 x 2625	00-A-0005
26	WASTE OIL TANK	4920 x 2220 x 1601	00-T-0007
27	OPEN DRAIN SUMP (PURACEPTOR)	Φ1800 x 5900L	00-T-0002
28	SALES GAS METERING PACKAGE	13500 x 3500	50-A-0001
29	PIG LAUNCHER	-	-
30	LUBE OIL COALESCER PACKAGE	7810 x 2700	00-A-0003
31	ESSENTIAL DIESEL GENERATOR (FUTURE)	-	-
32	DIESEL STORAGE TANK (FUTURE)	-	-
33	-	-	-
34	-	-	-
35	-	-	-

NOTES:

1. NORTHING AND EASTING COORDINATES ARE REFERENCED IN RELATION TO THE LOCAL FIELD COMPRESSOR STATION GRID SYSTEM. CONVERSION FROM THE LOCAL FIELD COMPRESSOR STATION GRID SYSTEM TO TRUE COORDINATES SHALL BE CONFIRMED BY SITE SURVEY PRIOR TO DETAILED ENGINEERING.
2. EXPORT GAS PIPELINE, TREATED AND CLEAN PRODUCED WATER PIPELINE AND GATHERING NETWORK PIPELINE ALIGNMENT. PRELIMINARY ROUTING SHOWN FOR INFORMATION ONLY.
3. POWER STATION DESIGN BY OTHERS. SEE DRAWING# S00B01-ARW-CIV-LAY-00001.

EQUINOX PROJECT No. 910-00-08

REFERENCE DRAWING NUMBER	REFERENCE DRAWING TITLE	REV	DATE	REVISION DESCRIPTION	ORIG	CHK	QA	APP
-	-	A	06/10/22	ISSUED FOR REVIEW	RJM			

RPEQ CERTIFICATION
Signature
Name: BRAHAM SINGH
RPEQ No.: 15622
Date: 23.08.22

SITE	PLANT	PROJECT CODE
S00	N01	A275

SECURITY CLASSIFICATION: RESTRICTED

GIRRAHWEEN
SURAT GAS PROJECT
FIELD COMPRESSION STATION
PLOT PLAN

STATUS: IFR
CONTRACTOR DRAWING NUMBER: -
ARROW ENERGY DRAWING NUMBER: S00N01-ARW-CIV-LAY-00001
SCALE: 1:1000
REV: A
SIZE: A1

2022-10-11 - 9:53 AM Ryan Matthews, Brisbane
S00N01-ARW-CIV-LAY-00001.DWG
ARROW-A1 BORDER
ORG-ARW-PMC-TEM-00022 REV 2

1.2 Scope of Work

The scope of work for the AQIA was as follows:

- Confirm relevant regulatory criteria for relevant air pollutants, such as those set out in the *Queensland Environmental Protection (Air) Policy* (EPP Air 2019).
- Characterise the background ambient air quality to enable an assessment of cumulative impacts. This included a review of air quality data collected by the nearest Southwest Air Quality Monitoring Station (AQMS) located at Miles.
- Perform a generic assessment of multi well pad emissions to identify separation distances, based on dispersion modelling using nominal air emissions data and the three-dimensional meteorological dataset compiled for the site.
- Review site layout plan, stack parameters and emissions data for key air pollutants (NO_X and CO) provided by Arrow for the proposed FCS operations.
- Model emissions of NO_x and CO from on-site CSG combustion sources (eg. gas generators, flares) to predict maximum downwind ground level pollutant concentrations for normal and flaring operational scenarios using the CALPUFF dispersion model. Based on the results of the dispersion modelling, assess the potential impacts on local air quality associated with the operation of this facility.

2.0 Regulatory Framework

2.1 National Environment Protection Measure for Ambient Air Quality

The *National Environment Protection (Ambient Air Quality) Measure* (NEPM AAQ) (NEPC 2021) provides a nationally consistent framework for jurisdictions to monitor and report ambient air quality through setting reporting standards for key air pollutants. The NEPM AAQ contains standards and goals for six common air pollutants, commonly referred to as *criteria pollutants*. The current NEPM AAQ standards for those pollutants relevant to this assessment (as updated on 18 May 2021) are presented in **Table 1**.

It is noted that the NEPM AAQ standards apply at performance monitoring locations. Performance monitoring stations are to be located so that they provide a representative measure of the air quality likely to be experienced by the general population in the region or sub-region. The NEPM AAQ standards are therefore not intended for use in assessing air quality impacts from individual sources, specific industries or roadside locations. Nonetheless, many State regulatory agencies, including DES (see **Section 2.2**), have adopted them as air quality impact assessment criteria for use in AQIAs.

Table 1 NEPM AAQ Standards and Goals for Criteria Pollutants

Indicator	Maximum Concentration Standard		Averaging Period
	µg/m³ at 0°C	ppm	
NO_2	162	0.08	1-hour
	30	0.015	Annual
CO	11,100	9.0	8 hours

2.2 Queensland EPP (Air) Policy 2019

The *Environmental Protection (Air) Policy* (EPP (Air)) (EPP Air 2019) is designed to achieve the objectives of the *Environmental Protection Act 1994* in relation to the air environment. The purpose of the EPP (Air) is achieved by identifying environmental values to be enhanced or protected, outlining indicators and air quality objectives for enhancing or protecting these values and providing a framework for making consistent, equitable and informed decisions about the air environment.

The environmental values listed in the EPP (Air) that are to be enhanced or protected under the policy are:

- *The qualities of the air environment that are conducive to protecting the health and biodiversity of ecosystems; and*
- *The qualities of the air environment that are conducive to human health and wellbeing; and*
- *The qualities of the air environment that are conducive to protecting the aesthetics of the environment, including the appearance of buildings, structures and other property; and*
- *The qualities of the air environment that are conducive to protecting agricultural use of the environment.*

A number of air quality objectives are outlined within Schedule 1 of the EPP (Air) to protect these environmental values. Those related to this AQIA are reproduced in **Table 2**.

It is noted that the health and wellbeing air quality objectives listed in the EPP (Air) for NO_2 are based on the NEPM AAQ standards prior to the latest update of the Measure in May 2021. It is understood that the EPP (Air) is in the process of being amended to reflect the recent changes to the AAQ NEPM, so while this AQIA has adopted the current EPP Air (2019) objectives, consideration has also been given to compliance with the reduced NEPM AAQ NO_2 standards.

As shown in **Table 2**, the EPP (Air) currently also includes an air quality objective for NO_2 to protect the health and biodiversity of ecosystems. The EHP Guideline *Application requirements for activities with impacts to air* (DEHP 2017) states:

> *'If a proposal involves the release of contaminants to air in a location where natural ecosystems may be affected (e.g. adjacent to national parks), the applicant must identify whether emissions are at levels that may impact on the health and biodiversity of the ecosystem.'*

Given that the NEPM AAQ standard for annual average NO_2 concentrations is slightly lower than the EPP (Air) annual average air quality objective NO_2 for ecological impacts, only the NEPM AAQ standard has been considered, for simplicity.

Table 2 Relevant EPP (Air) 2019 Ambient Air Quality Objectives

Indicator	Environmental Value	Air Quality Objectives		Averaging Period
		µg/m³ at 0°C	ppm	
NO_2	Health and wellbeing	250	0.12	1-hour
		62	0.03	Annual
	Health and biodiversity of ecosystems	33	0.016	Annual
CO	Health and wellbeing	11,000	9.0	8 hours

Section 9 of the EPP (Air) also sets out a management hierarchy for all activities involving air emissions:

- Firstly - **avoid** (e.g. using technology that avoids air emissions);
- Secondly - **recycle** (e.g. re-using air emissions in another industrial process);
- Thirdly - **minimise** (e.g. treating air emissions before disposal); and
- Fourthly - **manage** (e.g. locating an activity that releases air emissions in a suitable area to minimise the impact of the air emissions).

2.3 Air Quality Criteria Adopted in this Assessment

The ground level ambient air quality criteria that are considered appropriate for this air quality assessment are summarised in **Table 3**.

Table 3 Ground Level Concentration Criteria Adopted for use in this Study

Indicator	Averaging Period	Criterion (µg/m³ at 0°C)	Reference
NO_2	1 hour	250	EPP (Air) 2019
		162	*NEPM AAQ (2021)*
	1 year	62	EPP (Air) 2019
		30	*NEPM AAQ (2021)*
CO	8 hours	11,000	EPP (Air) 2019

3.0 Site Description

3.1 Site Locations

As outlined in **Section 1.0**, the proposed Girrahween FCS site is located approximately 18 km north of Miles in the Surat Basin in the Darling Downs region of Queensland.

The areas surrounding the site are predominantly rural in nature, with land uses such as grazing, pre-existing gas field development and overlapping mining tenures dominating. Existing road infrastructure typically includes a number of rural secondary roads linking the major regional road network, as well as numerous CSG field access roads and mining activities.

3.2 Climate and Meteorology

The nearest available meteorological monitoring stations collecting data suitable for use in a quantitative air dispersion modelling study operated by the Bureau of Meteorology (BoM) are located at Miles. The following description of the regional climate is based on long term data reported from Miles Constance Street (Station 042112, elevation 305 m), located 19 km from the Girrahween FCS, which has data available from 1992 to 2023 for the following parameters:

- Temperature (°C)
- Rainfall (mm)
- Solar radiation (MJ/m^2)
- Relative humidity (%)
- Cloud cover
- Wind speed (m/s) and wind direction (degrees).

A review of the long term data available is provided in the following sections.

3.2.1 Temperature

Long-term temperature statistics for Miles Constance Street are summarised in **Figure 2**. Mean maximum temperatures range from 20.2°C in winter to 33.9°C in summer, while mean minimum temperatures range from 4.4°C in winter to around 20.5°C in summer. Maximum temperatures above 40°C and minimum temperatures less than -4°C have been recorded.

3.2.2 Rainfall

Long-term rainfall statistics for Miles Constance Street are summarised in **Figure 3**. The average monthly rainfall is relatively high in summer, reducing from autumn to winter with the lowest average of 21.6 mm/month recorded during July. This month also recorded an average of around five rain days per month. The highest average monthly rainfall of 86.6 mm/month occurs in December, with an average of 9 rain days recorded in this month. The highest monthly rainfall recorded over the time period examined was 340 mm recorded in December 2010. Peak rainfall events occur during summer, with the maximum daily rainfall of 116 mm recorded on 9 February 1998.

Figure 2 Long Term Temperature Data for Miles Constance Street

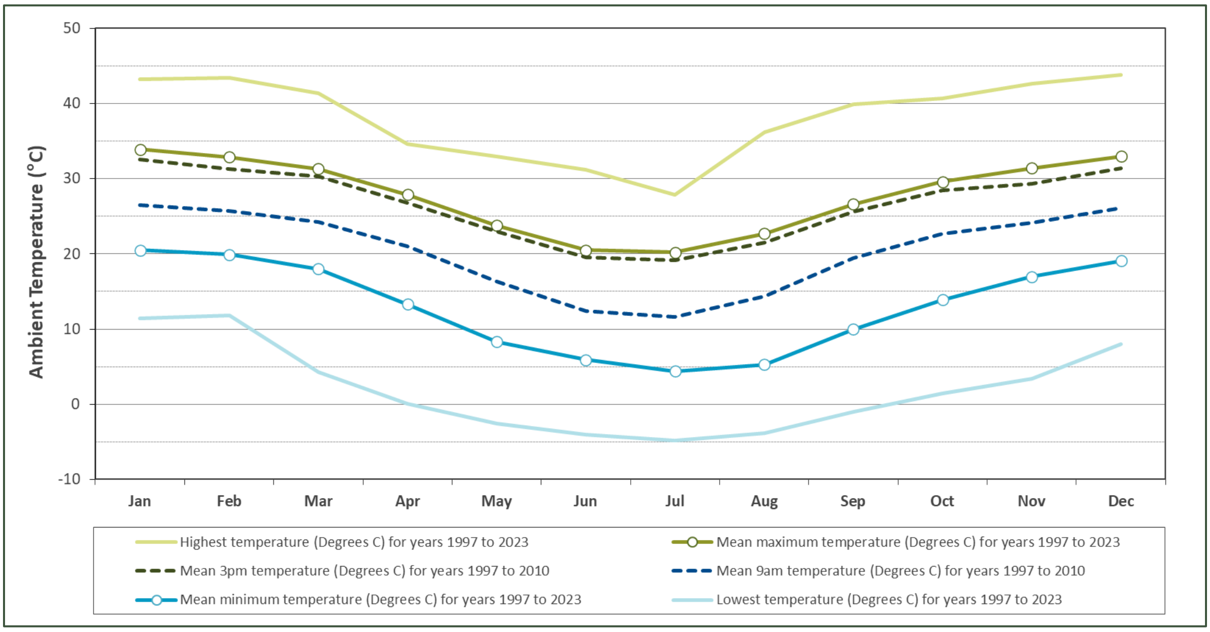
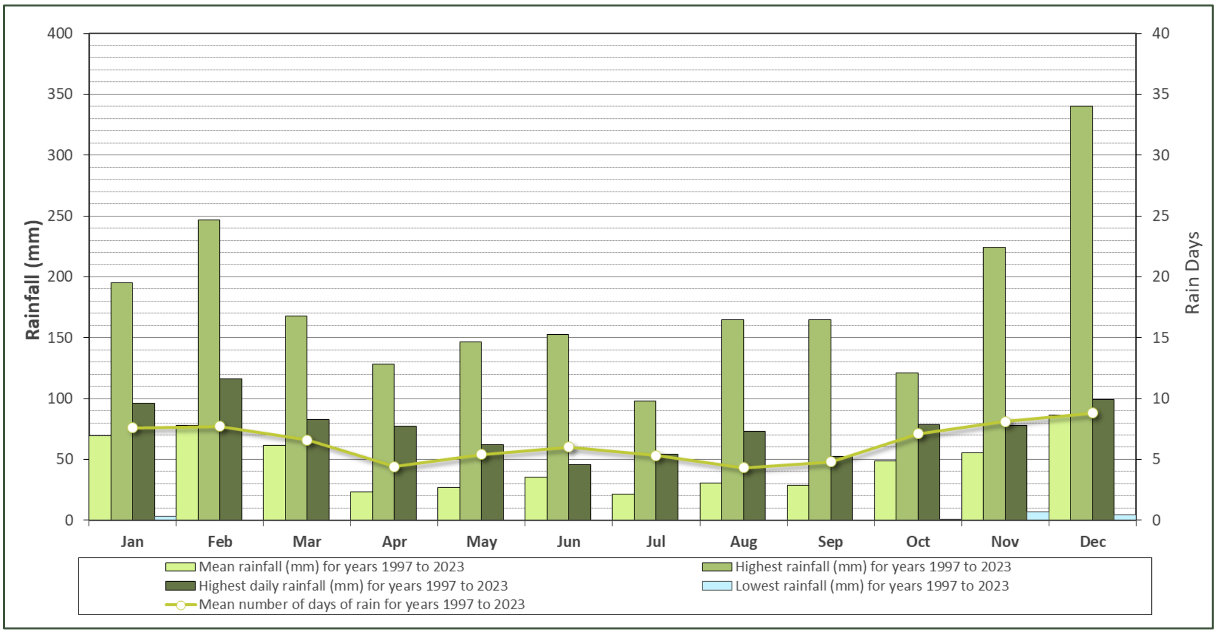


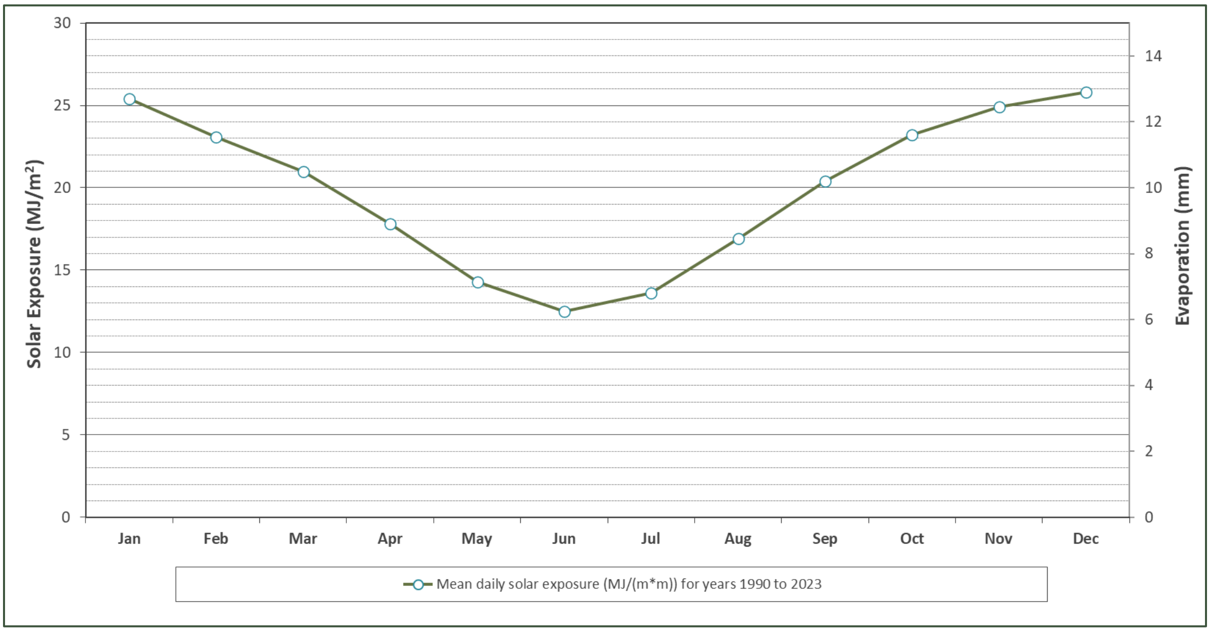
Figure 3 Long Term Monthly Rainfall Data for Miles Constance Street



3.2.3 Solar Radiation

As would be expected, the mean daily solar exposure levels recorded at Miles Constance Street (see **Figure 4**) are highest in summer (peaking at 25.8 MJ/m^2 in December) and lower in winter (dropping to 12.5 MJ/m^2 in June).

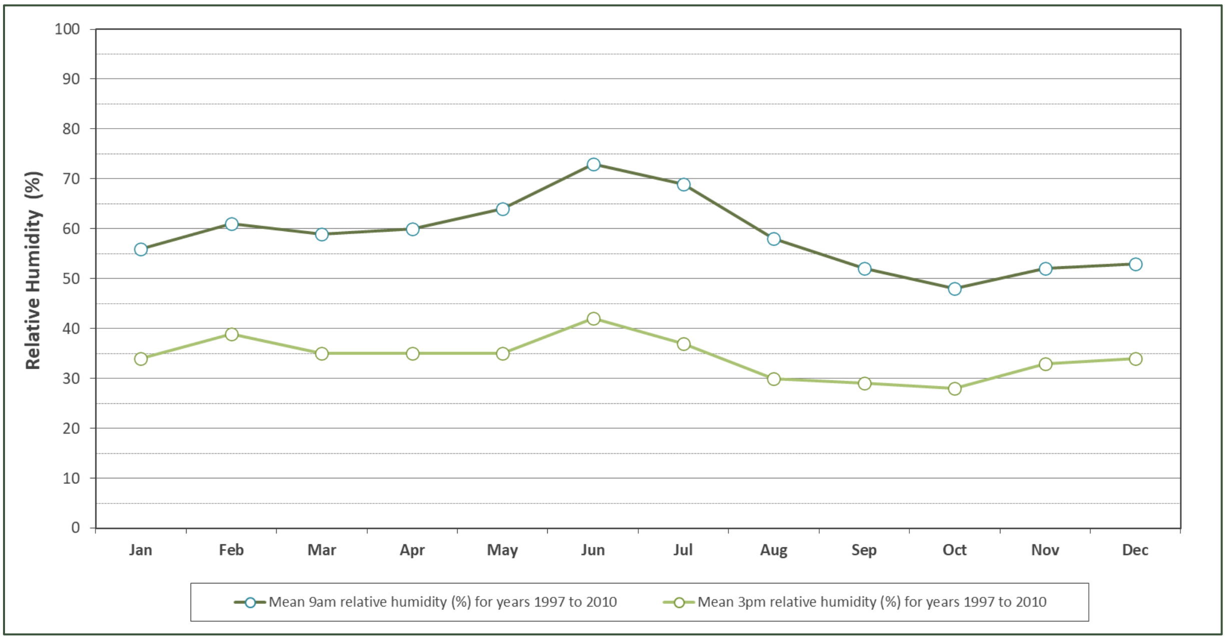
Figure 4 Long Term Solar Radiation Data for Miles Constance Street



3.2.4 Relative Humidity

Long-term humidity statistics (9 am and 3 pm monthly averages) for Miles Constance Street are summarised in **Figure 5**. Morning humidity levels range from an average of around 73% in early winter to around 59% in mid-spring. Afternoon humidity levels are lower, at around 49% in summer and dropping to a low of 48% in mid of spring.

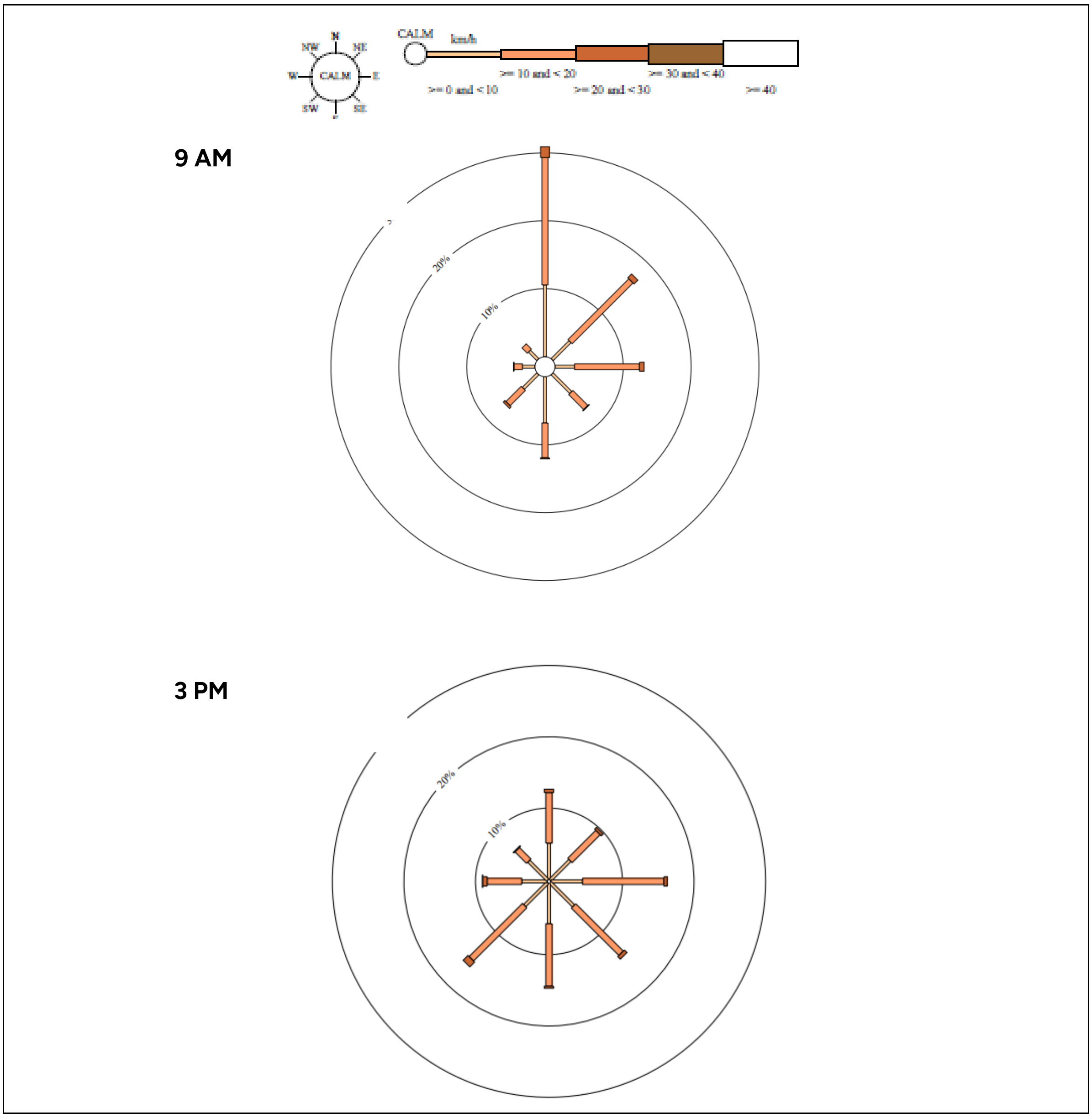
Figure 5 Long Term Humidity Data for Miles Constance Street



3.2.5 Wind Speed and Direction

Long term wind data (9 am and 3 pm) for Miles Constance Street are presented as wind roses in **Figure 6**. The wind roses show that winds from north are predominant in the morning and winds are evenly distributed in the afternoon periods, with a relatively low frequency of westerly winds also evident in the afternoon.

Figure 6 Rose of Wind Direction vs Wind Speed (km/hr) at Miles Constance Street (1992 - 2022)

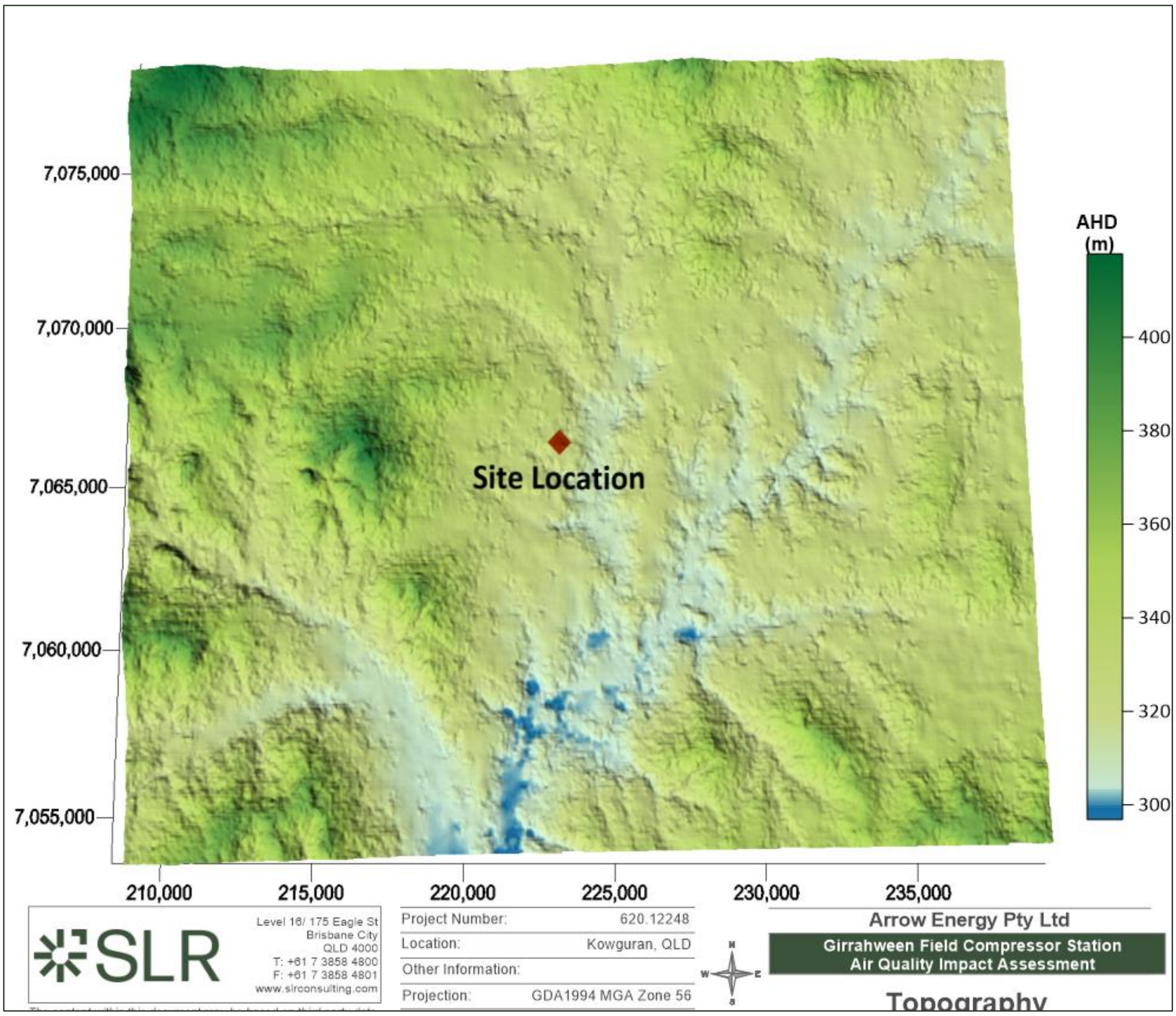


3.3 Topography and Landuse

The land surrounding the Project site is rural in nature. The site is located in an area with relatively complex topography at an elevation of 380 m.

For this study, topographical data was sourced from the Shuttle Radar Topography Mission (SRTM) database, which obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth. There are two resolution outputs available, 1 km and 90 m resolutions. SRTM data with 90 m resolution was input into the CALMET model to characterise terrain heights within the model domain, as presented in **Figure 7**.

Figure 7 Local Topography



3.4 Existing Air Quality Environment

Ambient air quality criteria relate to the total cumulative pollutant concentration that the population may be exposed to. Air dispersion modelling assessments therefore require the background air quality to be characterised, so that background concentrations of key pollutants of interest can be added to the incremental impacts predicted as a result of the modelled emission sources to provide an assessment of cumulative impacts.

In collaboration with industry partners, DES operates an air quality monitoring network across southwest Queensland to monitor for any air quality impacts associated with the intensive CSG production activities in the Western Downs region. These monitoring stations are located on properties near CSG infrastructure, including processing facilities and active gas wells. The AQMS located at Miles Airport is the nearest AQMS to the Girrahween FCS site. Given this, ambient air quality data recorded by the Miles Airport AQMS was used to estimate background CO and NO_2 levels for assessing cumulative impacts in this study.

Available validated NO_2 and CO concentration data recorded by the Miles monitoring stations during the 2020-2021 period are summarised in **Table 4** and presented as timeseries plots in **Figure 8** to **Figure 10**. It is noted that data records for the previous year (2019) had a very low data capture rate and data recorded in the 2022 calendar year are yet to be validated. Given this, the data recorded in 2019 and 2022 have not been considered in establishing site representative background levels.

A summary of the background pollutant levels adopted for this study is presented in **Table 5.**

Table 4 Summary of Review of Available Monitoring Data

Percentile	1-Hour Average NO_2 (µg/m³)		1-Hour Average O_3 (µg/m³)		8- Hour Average CO (µg/m³)	
	2020	2021	2020	2021	2020	2021
Maximum	63.6	49.2	128.4	117.7	500	1359
95th percentile	16.4	14.4	92.0	85.6	339	234
90th Percentile	12.3	10.3	87.7	79.2	283	203
70th Percentile	6.2	6.2	72.8	68.5	232	125
Average	5.9	6.1	59.6	57.7	173	136

Table 5 Adopted Background Levels for Assessing Cumulative Impacts

Pollutant	Averaging Period	Adopted Background Concentration (µg/m³)	Basis
NO_2	1-Hour	6.2	Maximum of 70th Percentile 1-hour average concentration recorded in 2020-2021 period
	Annual	6.1	Maximum annual average concentration recorded in 2020-2021 period
CO	8-Hour	232	Maximum of 70th Percentile 8-hour average concentration recorded in 2020-2021 period
O_3	1-Hour	72.8	Maximum of 70th Percentile 1-hour average concentration recorded in 2020-2021 period

Figure 8 Measured 1-Hour Average NO_2 Concentrations – Miles

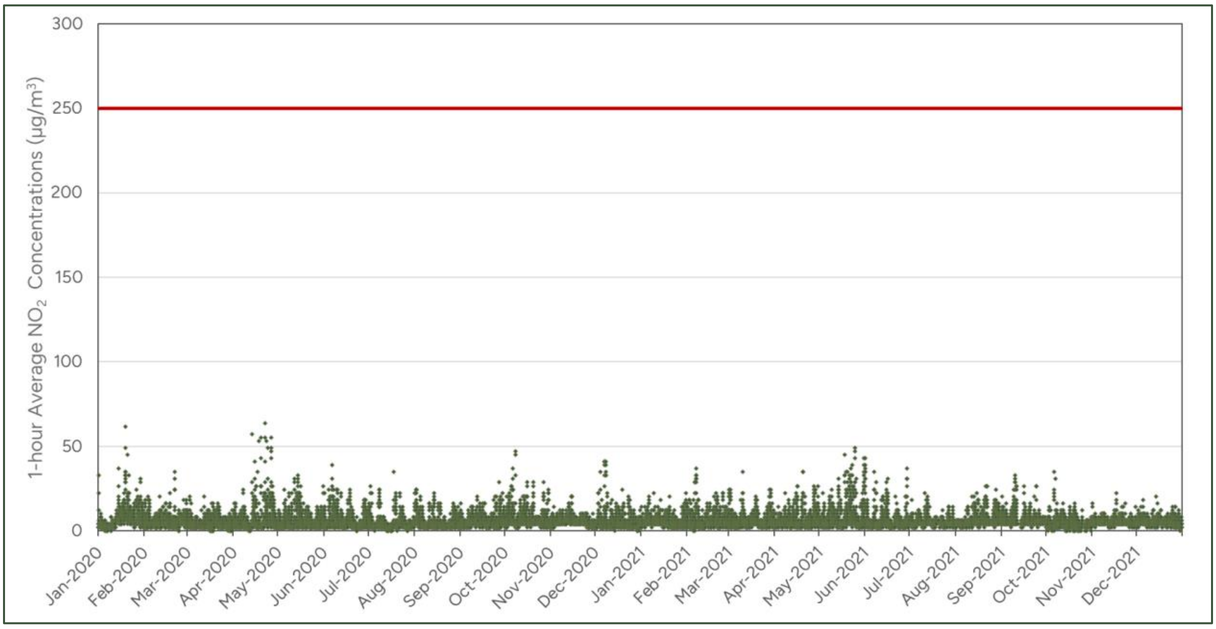


Figure 9 Measured 1-Hour Average O_3 Concentrations – Miles

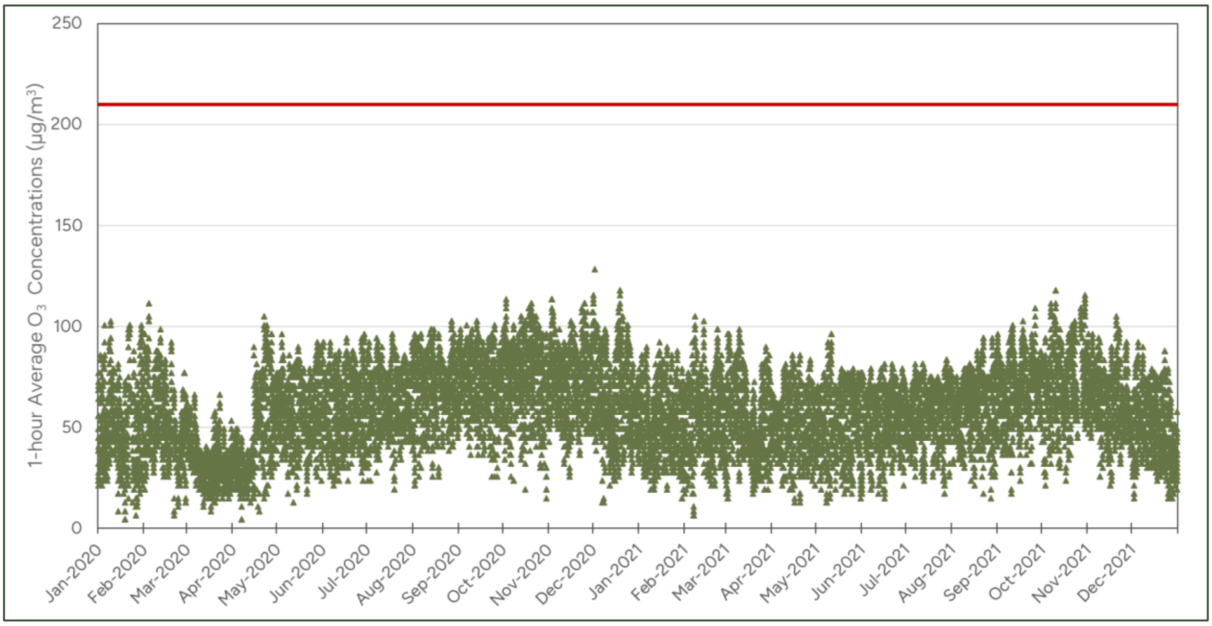
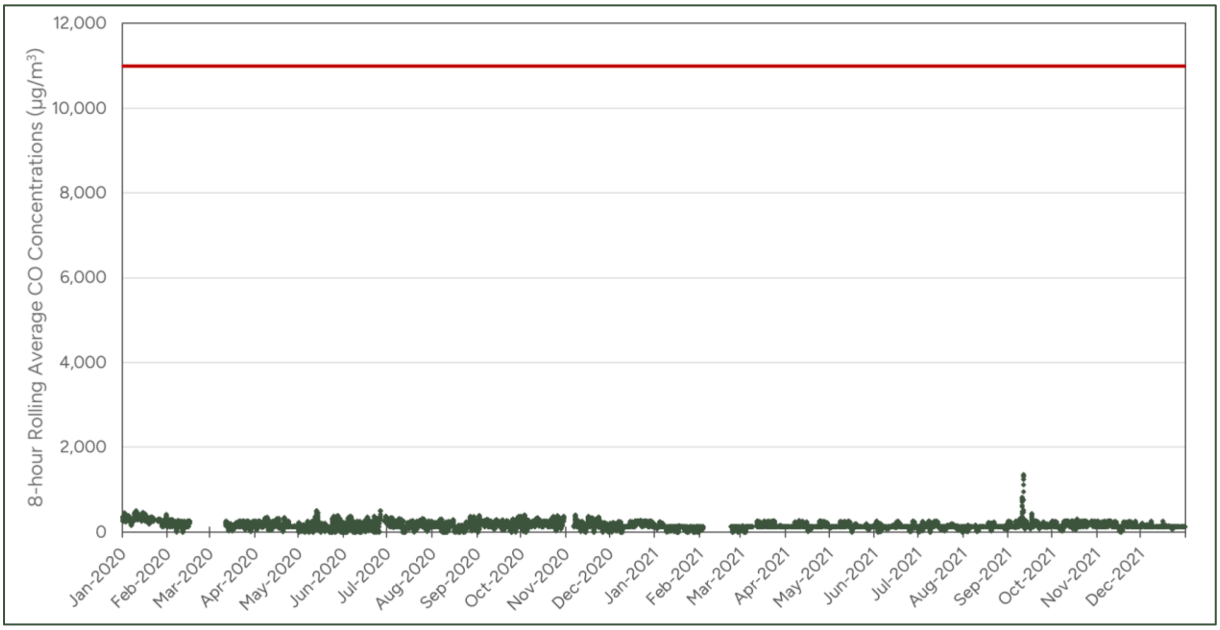


Figure 10 Measured 8-Hour Average CO Concentrations – Miles



3.5 Sensitive Receivers

The DES guideline, *Application requirements for petroleum activities* (DES 2016) defines sensitive receptors as follows:

> *A sensitive place could include but is not limited to:*
>
> - *A dwelling, residential allotment, mobile home or caravan park, residential marina or other residential premises*
> - *A motel, hotel or hostel*
> - *A kindergarten, school, university or other educational institution*
> - *A medical centre or hospital*
> - *A protected area under the Nature Conservation Act 1992, the Marine Parks Act 2004 or a World Heritage Area*
> - *A public park or garden*
> - *A place used as a workplace including an office for business or commercial purposes*.
>
> *Where there is potential for rezoning or subdivision of nearby land that may be impacted by air emissions, the applicant should also identify potential future land uses.*

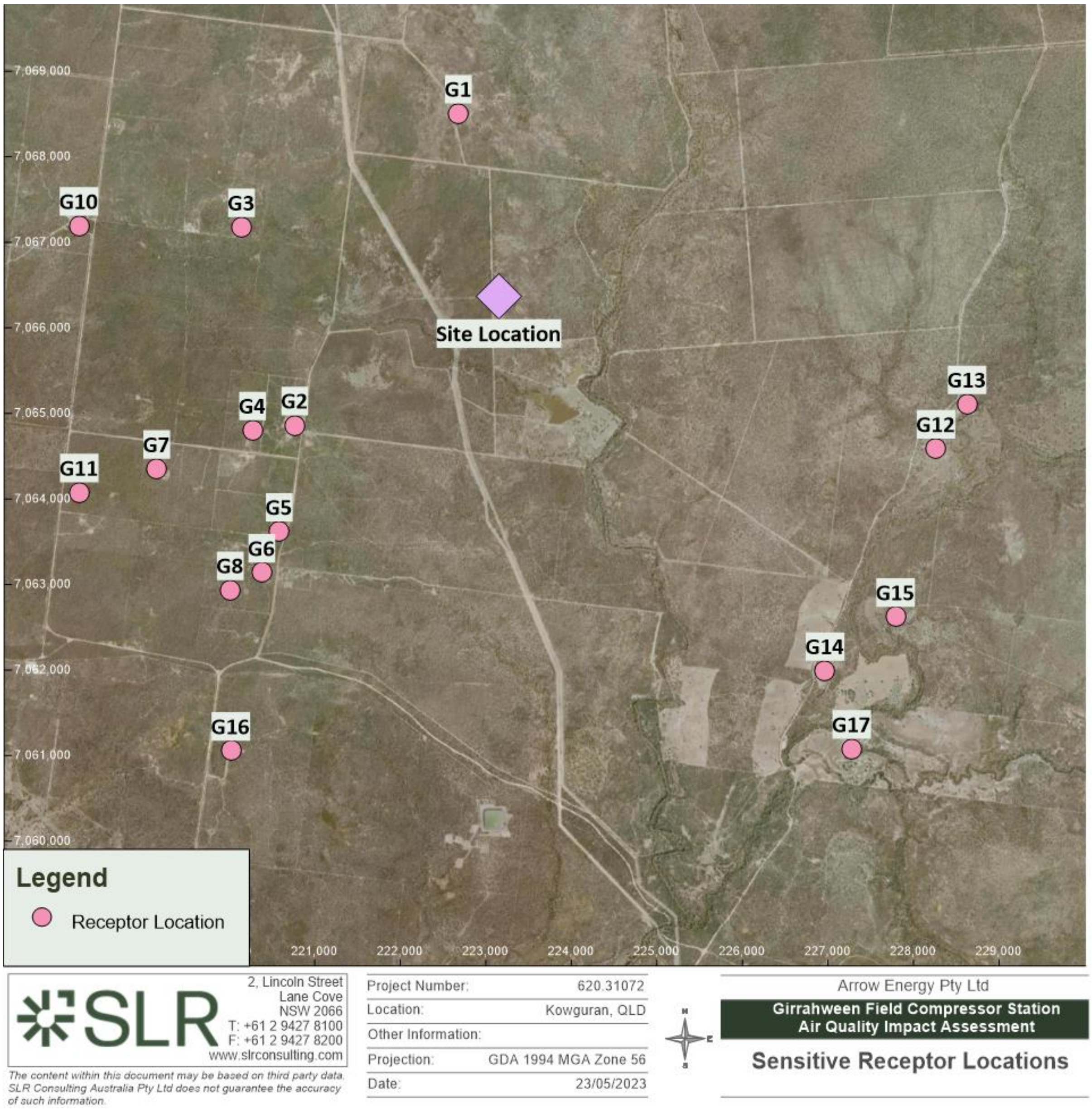
Information on sensitive receptors located in and around the Girrahween FCS site were provided by Arrow. Receptors identified as being located within 5 km of the Girrahween FCS are listed in **Table 6** and shown in **Figure 11**.

Note that all identified sensitive receptors in **Table 6** and **Figure 11** are dwellings/residential premises. No national parks or protected areas under the *Nature Conservation Act 1992, the Marine Parks Act 2004* or a World Heritage Area are identified in the study domain.

Table 6 Identified Sensitive Receptors within 5 km of Girrahween FCS

Receptor ID	Coordinates (GDA 94 zone 56)		Receptor ID	Coordinates (GDA 94 zone 56)	
	Easting	Northing		Easting	Northing
G1	222,680	7,068,507	G10	218,243	7,067,196
G2	220,766	7,064,862	G11	218,247	7,064,078
G3	220,144	7,067,178	G12	228,263	7,064,589
G4	220,272	7,064,803	G13	228,626	7,065,108
G5	220,584	7,063,619	G14	226,966	7,061,991
G6	220,381	7,063,139	G15	227,791	7,062,623
G7	219,152	7,064,353	G16	220,018	7,061,057
G8	220,013	7,062,935	G17	227,278	7,061,081

Figure 11 Identified Sensitive Receptors – Girrahween FCS



4.0 Assessment Methodology

4.1 Model Selection

Emissions from the proposed sources associated with the Girrahween FCS operation have been modelled using a combination of the Weather Research and Forecast (WRF), CALMET and CALPUFF models. CALPUFF is a transport and dispersion model that ejects "puffs" of material emitted from modelled sources, simulating dispersion and transformation processes along the way. In doing so it typically uses the fields generated by a meteorological pre-processor CALMET, discussed further below. Temporal and spatial variations in the meteorological fields selected are explicitly incorporated in the resulting distribution of puffs throughout a simulation period. The primary output files from CALPUFF contain either hourly concentration or hourly deposition fluxes evaluated at selected receptor locations. The CALPOST post-processor is then used to process these files, producing tabulations that summarise results of the simulation for user-selected averaging periods.

CALPUFF is a widely used model in assessing potential air quality impacts associated with CSG operations in Queensland and has been adopted for this assessment.

4.2 Selection of Representative Year

Five years (2013-2017) of meteorological data recorded by the BoM's Miles Constance Street station (Station ID 42112) were analysed and investigated to identify a suitable representative year for use in the modelling. Based on this analysis, the calendar years 2015 and 2016 were identified as the most representative years.

As meteorological monitoring data from Arrow's weather stations located near the Tipton and Daandine CGPFs are available for 2016, the 2016 calendar year was selected as the modelling year for this assessment.

4.3 Meteorological Modelling

4.3.1 Weather Research and Forecast (WRF)

The Weather Research and Forecast (WRF) model is a next generation mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting needs. It features two dynamical cores; a data assimilation system and a software architecture facilitating parallel computation and system extensibility. The model serves a wide range of meteorological applications across scales from tens of meters to thousands of kilometres.

For this assessment, the WRF modelling system was used to produce the meteorological field required as input for the outer domain of the CALMET meteorological model. Parameters used in the WRF model for this assessment are presented in **Table 7**.

Table 7 Meteorological Parameters – WRF Modelling

Parameter	Domain 1	Domain 2
Modelling domain	2,100 km × 2,100 km	310 km × 310 km
Grid resolution	30 km	10 km
Number of vertical levels	30	30
Microphysics	WSM6 [1]	WSM6
Cumulus parameterisation	Kain-Fritsch Scheme [2]	Kain-Fritsch Scheme
Shortwave radiation physics	Dudhia Scheme [3]	Dudhia Scheme
Longwave radiation physics	Rapid Radiative Transfer Model (RRTM)[4]	RRTM
Planetary boundary layer	Yonsei University Scheme (YSU)	YSU

1. Single-Moment 6-Class Microphysics Scheme that represents cloud and precipitation processes (e.g. water vapour, cloud, ice, rain and snow).
2. Deep and shallow cumulus convection sub-grid scheme using a mass flux approach with downdrafts and convective available potential energy (CAPE) removal time scale.
3. Simple downward integration allowing efficiently for clouds and clear-sky absorption and scattering.
4. A Planetary Boundary Layer (PBL) scheme used to characterise meteorological processes in the PBL, such as near-surface temperature, relative humidity, wind speed and PBL Height, which accounts for multiple bands and microphysics species.
5. For further details refer to the WRF User Guide **(NCAR 2017)**.

4.3.1.1 CALMET

CALMET is a diagnostic meteorological model that develops wind and temperature fields on a 3-dimensional gridded modelling domain. Associated 2-dimensional fields such as mixing height, surface characteristics, and dispersion properties are also included in the file produced by CALMET. The interpolated wind field is then modified within the model to account for the influences of topography, as well as differential heating and surface roughness associated with different land uses across the modelling domain. These modifications are applied to the winds at each grid point to develop a final wind field. The final wind field thus reflects the influences of local topography and land uses.

CALMET modelling was conducted using the nested CALMET approach, where the final results from a coarse-grid run were used as the initial guess field for a middle grid run, which in turn provided the initial guess field for a fine-grid run. This has the advantage that off-domain terrain features including slope flows and blocking effects can be allowed to take effect and the larger-scale wind flows provide a more accurate initial conditions for the fine-grid run.

Initially an outer domain was modelled with a resolution of 3 km. WRF-generated 3-dimensional meteorological data were used as the initial-guess wind field, and local topography and land use information were used in CALMET to refine the wind field predetermined by the WRF data. Available observational data from Arrow-owned meteorological stations (Tipton and Daandine) and Bureau of Meteorology (BoM) operated stations in the surrounding area were also used as input to the CALMET model to refine the predicted meteorological data.

The output from the outer domain CALMET modelling was then used as the initial-guess field for the inner domain CALMET modelling. A horizontal grid spacing of 1 km and 0.25 km were used in the mid and inner domains respectively to adequately represent the important local terrain features and land use. Fine scale local topography and land use information were used in the inner domain run to refine the wind field parameters predetermined by the coarse CALMET runs.

Table 8 details the parameters used in the meteorological modelling to drive the CALMET model.

Table 8 CALMET Configuration Used for this Study

DOMAIN	DATA
Outer Domain	
Meteorological grid	150 km × 150 km
Meteorological grid resolution	3 km
Initial guess filed	3D output from WRF model
Mid Domain	
Meteorological grid	30 km × 30 km
Meteorological grid resolution	1 km
Initial guess field	3D output from outer domain modelling
Inner Domain	
Meteorological grid	25 km × 25 km
Meteorological grid resolution	0.25 km
Initial guess field	3D output from mid domain modelling

4.3.2 Summary of Meteorological Data Used in the Modelling

4.3.2.1 Wind Speed and Direction

A summary of the annual and seasonal wind behaviour predicted by CALMET for the Girrahween FCS site is presented as wind roses in **Figure 12**. Further information on the wind speed distributions is provided in **Figure 13**. These plots indicate that on an annual basis, the site predominantly experiences low to moderate wind speed conditions (between 1.0 m/s and 6 m/s), mainly from the south-eastern and northern quadrants. Calm wind conditions (wind speeds less than 0.5 m/s) were predicted to occur for about 1% of the time throughout the modelling period.

Figure 12 Annual and Seasonal Wind Roses as Predicted by CALMET for Girrahween FCS Site (2016)

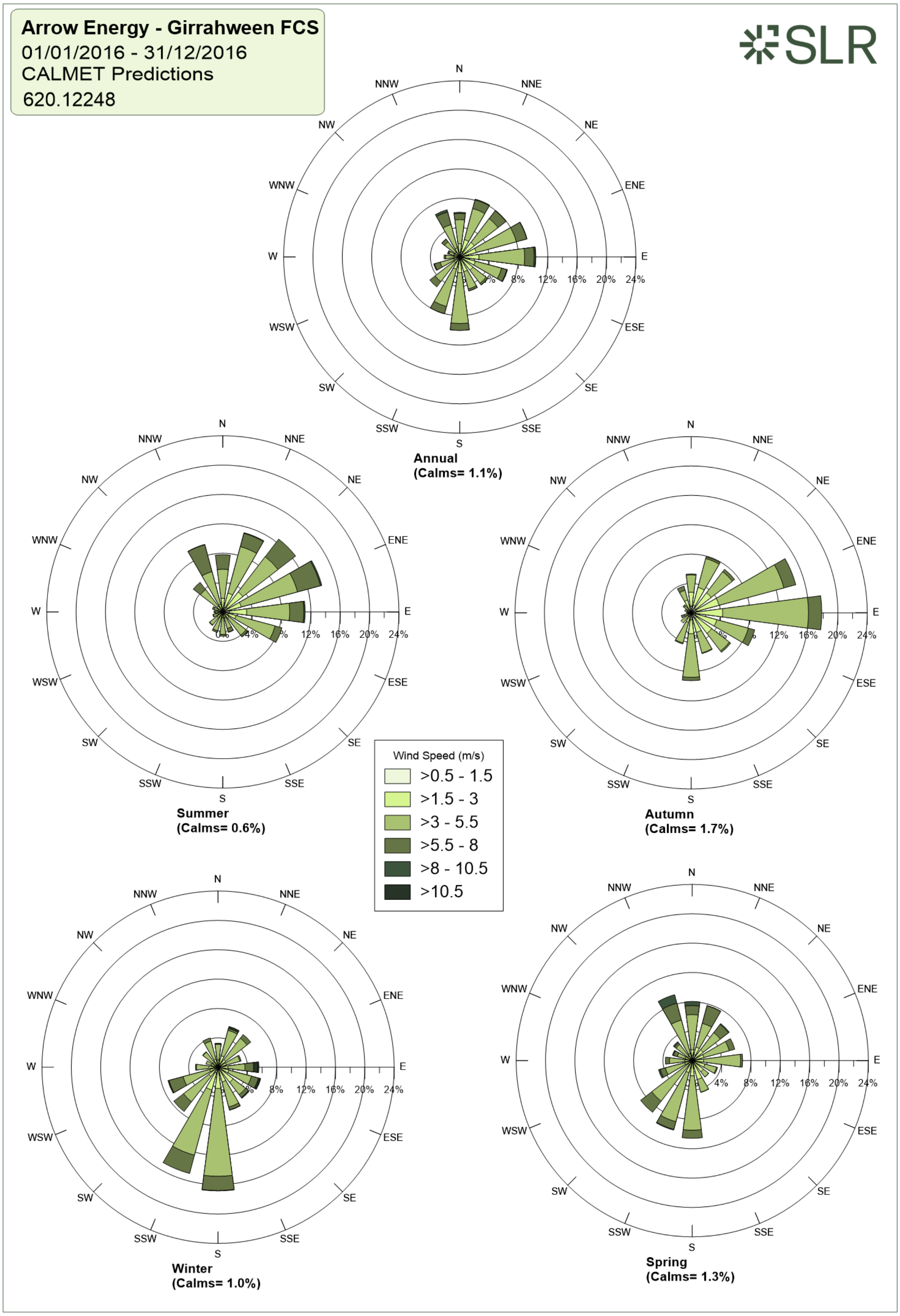
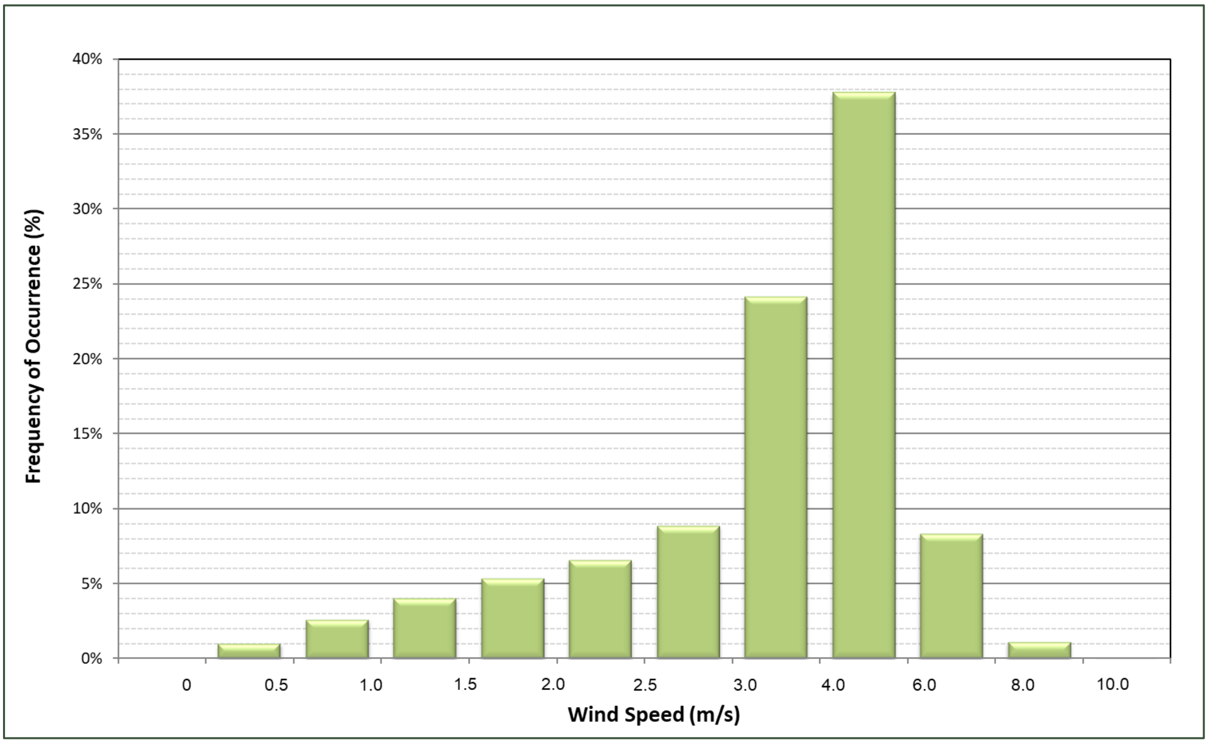


Figure 13 Wind Speed Distributions as Predicted by CALMET (2016) at Girrahween FCS Site



4.3.2.2 Atmospheric Stability

Atmospheric stability refers to the tendency of the atmosphere to resist or enhance vertical motion. The Pasquill-Gifford-Turner (PGT) assignment scheme identifies six Stability Classes, A to F, to categorise the degree of atmospheric stability as follows:

- A = Extremely unstable conditions
- B = Moderately unstable conditions
- C = Slightly unstable conditions
- D = Neutral conditions
- E = Slightly stable conditions
- F = Moderately stable conditions

The meteorological conditions defining each PGT stability class are shown in **Table 9** . The frequency of each stability class predicted by CALMET at the site during the modelling period is presented in **Figure 14**.

The results indicate a high frequency of conditions typical to stable conditions (Stability Class E and F), with a low frequency of very unstable conditions (Stability Class A). Stability Class E and F represent stable stability conditions that inhibit pollutant dispersion.

Table 9 Meteorological Conditions Defining PGT Stability Classes

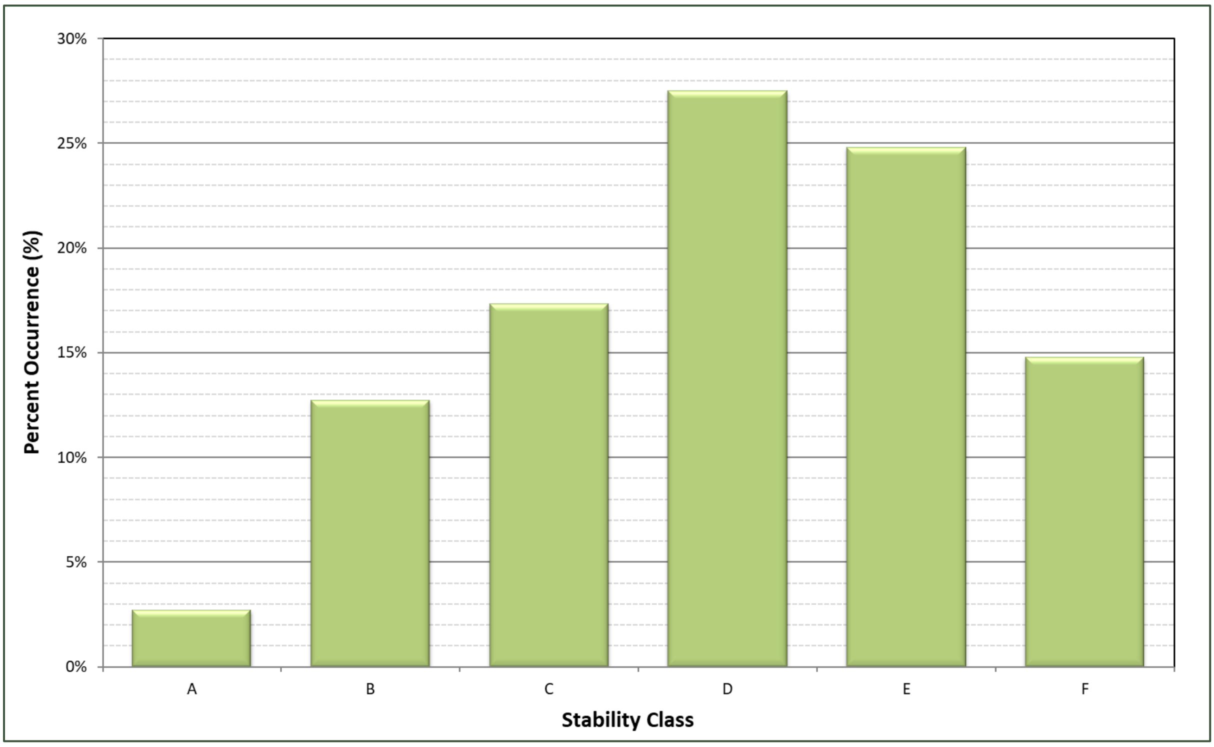
Surface Wind Speed (m/s)	Day-time Insolation			Night-time Conditions	
	Strong	Moderate	Slight	Thin overcast or > 4/8 low cloud	≤ 4/8 Cloudiness
< 2	A	A - B	B	E	F
2 - 3	A - B	B	C	E	F
3 - 5	B	B - C	C	D	E
5 - 6	C	C - D	D	D	D
> 6	C	D	D	D	D

SOURCE: (NOAA 2018)

Notes:

1. Strong insolation corresponds to sunny midday in midsummer in England; slight insolation to similar conditions in midwinter.
2. Night refers to the period from 1 hour before sunset to 1 hour after sunrise.
3. The neutral category D should also be used, regardless of wind speed, for overcast conditions during day or night and for any sky conditions during the hour preceding or following night as defined above.

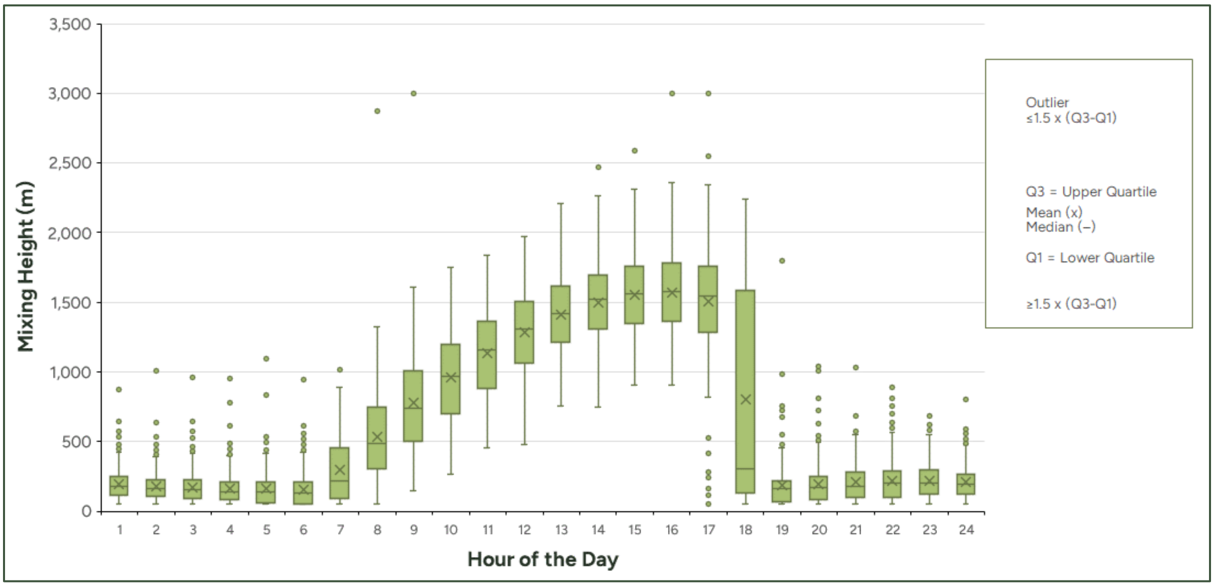
Figure 14 Stability Class as Predicted by CALMET (2016) at Girrahween FCS Site



4.3.2.3 Mixing Heights

Plots showing the diurnal variations in maximum and average mixing heights predicted by CALMET at the Girrahween FCS site during 2016 are provided in **Figure 15**. As would be expected, an increase in the mixing height during the morning is apparent at all locations, arising due to the onset of vertical mixing following sunrise. Maximum mixing heights occur in the mid to late afternoon, due to the dissipation of ground-based temperature inversions and the growth of the convective mixing layer.

Figure 15 Mixing Heights as Predicted by CALMET (2016) at Girrahween FCS Site



4.4 NO_X to NO_2 Conversion

NO_x emitted from combustion processes mainly consists of NO with a small portion (approximately 10%) of NO_2. In the atmosphere however, NO emitted from the source oxidises to NO_2 in the presence of O_3 and sunlight as it travels further from the source. The rate of oxidation depends on a number of parameters including the ambient O_3 concentration.

The *Approved Methods for Modelling and Assessment of Air Pollutants in NSW* (NSW EPA 2022) lists the following methods that can be applied to take account the oxidation of NO to NO_2 in estimating downwind NO_2 concentrations at receptor locations.

Method 1 – 100% Conversion

This method is usually used as a screening level assessment and assumes 100% conversion of NO to NO_2 before the plume arrives at the receptor location. Use of this method can significantly over-predict NO_2 concentrations at nearfield receptors.

Method 2 – Ambient Ozone Limiting Method (OLM)

This method assumes that all the available ozone in the atmosphere will react with NO in the plume until either all the O_3 or all the NO is used up. NO_2 concentrations can be estimated by this method using the following equation:

$$[NO_2]_{total} = \{0.1 \times [NO_x]_{pred}\} + MIN\{(0.9) \times [NO_x]_{pred} \text{ or } (46/48) \times [O_3]_{bkgd}\} + [NO_2]_{bkgd}$$

Again, when sensitive receptors are located close to the source, resulting in relatively short transport durations, Method 2 can be highly conservative as it assumes that the atmospheric reaction is instantaneous when in reality, the reaction takes place over a number of hours (NSW EPA 2022).

Method 3 – NO to NO_2 Conversion using Empirical Relationship

This method uses an empirical equation for estimating the oxidation rate of NO in power plant plumes dependent on distance downwind from the source and the parameters A and α, which has the following form:

$$NO_2 = NO_x \times A(1 - e^{-\alpha x})$$

where *x* is the distance from the source and A and α are classified according to the O_3 concentration, wind speed and season (Janssen, et al. 1988) as provided in **Table 10**.

Table 10 Classification of Values for A and α by Season

Season	Ozone (ppb)	Wind Speed (m/s)		
		5	15	>15
Winter	40	A = 0.87 α = 0.07	A = 0.87 α = 0.07	A = 0.87 α = 0.15
	30	A = 0.82 α = 0.07	A = 0.83 α = 0.07	A = 0.83 α = 0.07
	20	A = 0.74 α = 0.07	A = 0.74 α = 0.07	A = 0.74 α = 0.07
	10	A = 0.49 α = 0.05	A = 0.49 α = 0.05	A = 0.49 α = 0.05
Spring/Autumn	60	A = 0.85 α = 0.10	A = 0.85 α = 0.15	A = 0.85 α = 0.30
	40	A = 0.80 α = 0.10	A = 0.80 α = 0.10	A = 0.80 α = 0.25
	30	A = 0.74 α = 0.10	A = 0.74 α = 0.10	A = 0.74 α = 0.15
	20	A = 0.635 α = 0.10	A = 0.635 α = 0.10	A = 0.635 α = 0.10
Summer	200	A = 0.93 α = 0.40	A = 0.93 α = 0.65	A = 0.93 α = 0.80
	120	A = 0.88 α = 0.20	A = 0.88 α = 0.35	A = 0.88 α = 0.45
	60	A = 0.81 α = 0.15	A = 0.81 α = 0.25	A = 0.81 α = 0.35
	40	A = 0.74 α = 0.10	A = 0.74 α = 0.15	A = 0.74 α = 0.25
	30	A = 0.67 α = 0.10	A = 0.67 α = 0.10	A = 0.67 α = 0.10

Method 2, conversion of NO_x to NO_2 using the OLM was adopted for this assessment. Background ozone concentration data presented in **Section 3.4** was used in calculating NO_2 concentrations based on the model predicted NO_x concentrations in the surrounding areas.

5.0 Source Parameters

5.1 Modelling Scenarios

The emission sources modelled for both normal operating conditions and flare events are shown in **Table 11**.

Table 11 Modelling Scenarios

Source	Operational Scenario	Sources Modelled
Multi well pads	4 Genset skid	4 Shellby 60 kVA Gensets
	6 Genset skid	6 Shellby 60 kVA Gensets
Girrahween FCS	Normal operations	FCS power station (7 x 3.36 MW CSG-fired engines)
	Maximum flaring event	Multi point ground flare

As per the definitions provided in Schedule 2 *Queensland Environmental Protection Regulation 2019, a* "fuel burning or combustion facility" means permanent equipment that can burn more than 500 kg of fuel in an hour (DES, 2016). A six genset multiwell pad has the capacity of burning only 80 kg fuel per hour at maximum load.

Any fuel burning or combustion facility capable of burning less than 500 kg in an hour is not considered a significant risk to the environment, does not have an aggregate environmental score and has not been included as an environmentally relevant activity (ERA) in Schedule 2 of the *Environmental Protection Regulation 2008* (DES, 2016).

Air emissions for multiwell pads are included in this assessment for completeness, and to demonstrate that air emissions from multiwell pads would not give rise to any potential for exceedances of ambient air quality criteria.

5.2 Stack and Emission Data

5.2.1 Well Pad Emissions

Emissions from the well pad engines have been estimated based on measured engine testing data for the Shelby 60 kVA engine. Measured engine testing data provided to SLR by Arrow are summarised in **Table 12**. It is understood that, on an annual basis, these generators run at 50% load, however, are required to run at higher loads during initial dewatering.

Based on a review of the emission data presented in **Table 12** and considering the operational requirements, the stack parameters and emission rates associated with maximum load operating conditions were adopted for this assessment to predict the potential highest level of impacts within the receiving environment.

Modelling was performed based on the following:

- Locating the sources in a nominally central location within the meteorological file compiled for this study and described in **Section 1.2**.
- Two scenarios were assessed; one representing operations of a well pad with four gensets and the second representing a well pad with six gensets.

The incremental impacts predicted by the modelling were added to the adopted background levels outlined in **Section 3.4** to estimate minimum recommended separation distances for these sources that can be considered as part of the constraints analysis for locating well pads in the gas field.

Table 12 Measured Emission Data -Shellby 60 kVA Generator

Load	Exhaust Temperature	Stack Diameter	Exhaust Velocity	NO_x Emission	CO Emission
(kW)	(°C)	(m)	(m/s)	(g/s)	(g/s)
13	409	0.1	5.5	0.008	0.15
26	448	0.1	12.3	0.038	0.21
39	475	0.1	19.4	0.105	0.28
48	487	0.1	23.0	0.319	0.33

Air emissions were assessed at the maximum load and emission rates, in order to assess maximum potential air quality impacts from multiwell pad operation. The stack and emission data adopted for the gas gensets are presented in **Table 13.**

Table 13 Stack Parameters and Emission Data – Multiwell Pad Genset

Parameter	4 Genset Skid	6 Genset Skid
Number of generators	4	6
Stack height (m)	2.5	2.5
Stack diameter (m)	0.1	0.1
Exit velocity (m/s)	23	23
Exit temperature (°C)	487	487
NO_x (g/s)	0.32	0.32
CO (g/s)	0.33	0.33

5.2.2 Girrahween FCS Power Station

The stack and emission data provided by Arrow for the Girrahween FCS power station engines are summarised in **Table 14**.

Table 14 Model Inputs for the Girrahween Power Station – Normal Operations

Generator Stack	Easting	Northing	Stack Height	Exhaust Temperature	Stack Diameter	Minimum Velocity	NO_x Emission	CO Emission
	(m)	(m)	(m)	(°C)	(m)	(m/s)	(g/s)	(g/s)
1	223,700	7,065,368	5	500	0.283	32	1.5	0.4
2	223,711	7,065,368	5	500	0.283	32	1.5	0.4
3	223,722	7,065,368	5	500	0.283	32	1.5	0.4
4	223,733	7,065,368	5	500	0.283	32	1.5	0.4
5	223,700	7,065,394	5	500	0.283	32	1.5	0.4
6	223,711	7,065,394	5	500	0.283	32	1.5	0.4
7	223,722	7,065,394	5	500	0.283	32	1.5	0.4
8	223,733	7,065,394	Standby – not included in this assessment					

5.2.3 Multi Point Ground Flares

Flaring may occur at Girrahween FCS when a compressor trips or downstream capacity is restricted such that the gas being delivered to the facility (Girrawheen FCS) exceeds the delivery capacity. In these situations, gas must be flared until the well field can be turned down or compression/delivery capacity is restored. Flaring of gas occurs on rare occasions and is minimised to as low as reasonably practical (ALARP) through Arrow's advanced gas management.

In this study, modelling has been performed for the worst-case flaring scenario, based on the maximum design capacity of the flare. This scenario would only be expected to occur during unplanned events when plant is at full load and full facility shutdown occurs (eg. emergency shut down, loss of electrical power) which would be a highly infrequent event and has been chosen to provide an assessment of the maximum potential air quality impact from flaring operations.

The design data provided by Arrow for the MPGF is summarised in **Table 15**.

Table 15 MPGF Design Data

Flare	Easting	Northing	Design Capacity	Flare Height	Flare Diameter	Maximum Flaring Rate
	(m)	(m)	(MMscfd)	(m)	(m)	(MMscfd)
Girrahween flare	223,600	7,065,475	163	16.7	64.8	162.8

The following methodology was used to compile the stack and emission data required for modelling:

- NO_2 and CO emission rates were estimated based on the maximum flaring rate of each flare (converting from million standard cubic feet per day (MMscfd) to tonnes/day using a conservative gas density value of 0.73 kg/Sm^3) and emission factors of 1.5 kg/tonne NO_X and 8.7 kg/tonne CO from the National Pollutant Inventory (NPI) *Emission Estimation Technique Manual (EETM) for Oil and Gas Extraction and Production* (NPI 2013).
- Assumed flare temperature of 750°C
- Assumed vertical exit velocity of 20 m/s

6.0 Air Quality Impact Assessment

6.1 Normal Operations

The estimated NO_X and CO emissions listed in **Table 14** for Girrahween FCS under normal operating conditions have been modelled to predict maximum downwind, ground level NO_2 and CO concentrations. The maximum 1-hour and annual average NO_2 concentrations and 8-hour average CO concentrations predicted at the nearest identified sensitive receptors are presented in **Table 16** compared to the relevant ambient air quality criteria. As outlined in **Section 4.4**, the OLM was used to convert the NO_X predictions to NO_2 concentrations and the background concentrations estimated in **Table 5** have been used to estimate cumulative impacts.

Table 16 shows that the downwind NO_2 and CO concentrations predicted at the nearest sensitive receptors under normal operating conditions are far below the relevant air quality criteria and would not have potential to give rise to adverse air quality impacts at these locations. The modelling results presented in **Table 16** also shows that the predicted cumulative air quality impacts at the surrounding identified sensitive receptors are also well below the more stringent NEPM criteria for NO_2.

Contour plots of the maximum concentrations predicted across the modelling domain are presented in **Appendix A**.

Table 16 NO_X and CO Concentrations Predicted at the Nearest Sensitive Receptors – Girrahween FCS, Normal Operations

Receptor ID	NO_2 Concentrations (µg/m³)				CO Concentrations (µg/m³)	
	Maximum* 1-Hour Average		Annual Average		Maximum 8-Hour Average	
	Incremental Impact	Including Background	Incremental Impact	Including Background	Incremental Impact	Including Background
G1	87	93	1.8	7.9	32.1	264
G2	86	92	2.5	8.6	18.0	250
G3	86	92	1.8	7.9	20.2	252
G4	86	92	2.3	8.4	19.3	251
G5	87	93	2.4	8.5	30.0	262
G6	86	92	2.1	8.2	26.0	258
G7	83	89	1.9	8.0	17.0	249
G8	86	92	2.0	8.1	26.7	259
G10	79	86	1.2	7.3	10.2	242
G11	81	87	1.5	7.6	13.7	246
G12	34	40	0.2	6.3	4.0	236
G13	57	63	0.3	6.4	7.6	240
G14	31	37	0.2	6.3	3.7	236
G15	30	36	0.2	6.3	5.3	237
G16	80	86	1.2	7.3	21.9	254
G17	28	34	0.2	6.3	3.9	236
EPP (Air) Objective		**250**		**62**		**11,000**
NEPM AAQ Std		**162**		**30**		**11,000**

* Based on the 99.9th percentile prediction

6.2 Flaring Event

The estimated NO_X and CO emissions listed in **Table 15** for a flaring event at the Girrahween FCS have been modelled to predict maximum downwind, ground level NO_2 and CO concentrations. The maximum incremental 1-hour NO_2 concentrations and 8-hour CO concentrations predicted at the nearest identified sensitive receptors are presented in **Table 17**. OLM was used to convert the NO_X predictions to NO_2 concentrations as per **Section 4.4**

Annual average concentrations have not been presented as major flaring events only occur on rare occasions and would be operating for a short period only, hence a compliance assessment against the annual average criterion is not warranted.

Table 17 shows that the downwind incremental NO_2 and CO concentrations predicted at the nearest sensitive receptors during a major flaring event at the Girrahween FCS are negligible compared to the relevant air quality criteria presented in **Table 3**, and would not have potential to give rise to any significant adverse air quality impacts at these locations.

Contour plots of the maximum concentrations predicted across the modelling domain are presented in **Appendix B**.

Table 17 NO_2 and CO Concentrations Predicted at the Nearest Sensitive Receptors – Girrahween FCS, Flaring

Receptor ID	Incremental Impacts (µg/m³)	
	99.9th Percentile 1-Hour Average NO_2	Maximum 8-Hour Average CO [a]
G1	0.2	3.2
G2	0.2	2.5
G3	0.3	2.2
G4	0.2	2.6
G5	0.1	2.6
G6	0.1	2.2
G7	0.1	2.4
G8	0.1	2.0
G10	0.3	1.8
G11	0.1	1.9
G12	0.1	0.5
G13	0.1	0.6
G14	0.1	0.6
G15	0.1	0.6
G16	0.1	1.1
G17	0.1	0.6

6.3 Well Pad Emissions

The estimated maximum NO_X emissions listed in **Table 12** for the well pad gensets have been modelled using the meteorological file compiled for the Girrahween FCS site, with the emission sources nominally located at the centre of the modelling domain. To enable a more refined assessment of near source predictions, the modelling was performed using a finer resolution 2 km by 2 km nested meteorological domain, centred on the emission source, which had a 25 m grid spacing.

The predicted downwind NO_X concentrations were then post-processed to calculate the maximum ground level NO_2 concentration predicted in any direction downwind (using OLM for NO_x to NO_2 conversion calculation as per **Section 4.4**). The resulting incremental concentration-distance profile for each type of well pad are shown in **Figure 16**.

Figure 16 Maximum Predicted Incremental NO_2 Concentrations

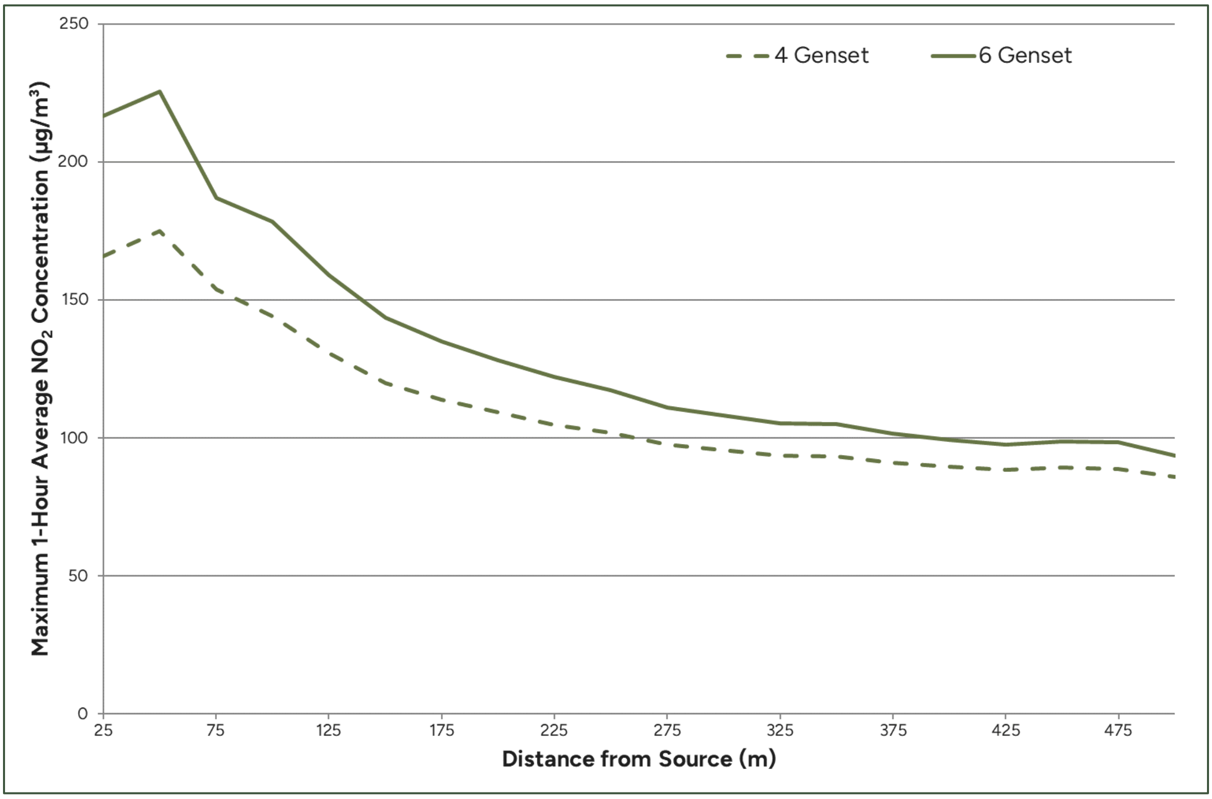


Figure 16 shows that the maximum predicted incremental NO_2 concentrations are below the current EPP (Air) 1-hour average ground level NO_2 criterion of 250 µg/m^3 within a very short distance (<25 m) of the source for both categories of well pad. Considering the adopted background 1-hour average NO_2 concentration of 6.2 µg/m^3 and given that the CALPUFF dispersion model is likely to overestimate the impacts in the very nearfield, as well as the low probability of these gensets operating at maximum load for a prolonged period, the cumulative 1-hour average ground level NO_2 concentrations are highly unlikely to exceed the current EPP (Air) air quality objective of 250 µg/m^3 at the surrounding area in the vicinity of the well pads.

Multiwell pads are all located much greater than 500 m from a sensitive receptor due to noise constraints. Given this and considering that a separation distance greater than 500 m would be required for noise mitigation, the NO_2 modelling results do not identify any air quality constraints for well pad operations. Air emissions from single vertical wells with a single genset have been previously assessed and were shown to achieve the air quality criterion for NO_2 within 200 metres of the source.

If the more stringent NEPM AAQ guideline of 162 µg/m^3 was adopted, a separation distance of 200 m would be adequate to avoid the potential for any non-compliances at nearby areas for either category of well pad.

Considering that CO emission rates for the well pad gensets are similar to those estimated for the NO_X emissions (see **Table 12**) and the relevant CO guideline outlined in **Table 3** is much higher, CO emissions can be concluded to also not result in any air quality constraints for well pad operations.

Based on the above, a minimum recommended separation distance of 200 m for well pads would be adequate for avoiding any adverse air quality impacts at nearby sensitive receptors.

7.0 Mitigation and Monitoring

This AQIA impact assessment has not identified any potential for adverse air quality impacts associated with the proposed FCS of well pad operations. Nonetheless, the design and operation of the facilities will be undertaken to minimise and manage emissions from the plant as outlined below.

7.1 Mitigation Measures

Arrow is committed to applying a hierarchy of controls in order to minimise environmental impact. Arrow has standard operating procedures determining how selection of equipment will be completed in regard to protecting environmental values. Equipment that results in environmental impact will be:

- Avoided
- Substituted out
- Have mitigations imposed to reduce the impact.

In order to determine what equipment should be installed for the project (and therefore what equipment should be avoided), equipment selection will consider as part of the assessment process:

- Low source of noise emissions
- Low emissions to air
- High energy efficiency and fuel efficiency
- Low generation of waste
- Low greenhouse gas emissions
- Avoidance of ozone depleting substances
- Avoidance of particularly hazardous chemicals
- Low emissions of pollutants to water
- Low water use.

Across all of Arrow's SGP activities, Arrow has committed to the mitigation measures listed in **Table 18** to minimise air quality impacts. These measures are recorded in standard operating procedures included in the Surat Gas Project operating model.

In addition to these measures, Arrow is committed to selecting sites for project infrastructure that will protect the environmental values of the project development area wherever practicable. The objectives of site selection are to:

- Ensure the selection of optimal, environmentally acceptable sites for infrastructure placement.
- Avoid or eliminate potential impacts to environmental values.
- Minimise, to the greatest extent practicable, potential impacts to environmental values unable to be avoided or eliminated during design.
- Identify environmental measures for low, moderate and highly constrained areas and 'No Go' such areas.

Modelling of emissions from CSG-fired generators that would be installed at well pads as part of the SGP, as presented in this report, indicates that to ensure that ground-level NO_2 concentrations meet guideline criteria, well pads should be located no closer than 200 m from sensitive receptors.

Table 18 Mitigation Commitments

Project Phase	Mitigation Measures
Operational Phase	• Implement a preventative maintenance program to ensure engines are operating efficiently to minimise NO_X, CO, methane and VOC emissions. • Implement a quantifiable monitoring and measuring program. • Roads, access tracks and other areas may be watered to suppress dust. Vehicle travelling speeds will be restricted, and movements will be limited to approved access tracks. • Selection of gaskets, seals and vehicle exhaust systems that are suitable for the task, and maintained according to manufacturer's recommendations. • Manufacturer's recommendations and guidelines with respect to air emissions control systems are followed at all times. • Air pollution control technologies are to be maintained in good working order and kept in place at all times the equipment is operating. • Air emissions will be monitored at the source in accordance with the corresponding Environmental Authority conditions. • Equipment that produces abnormal monitoring results will trigger maintenance /review procedures to return emissions to acceptable levels. Where practical, the equipment should not be brought back into service until normal operational emissions are achieved.
Vehicles and machinery	• Ensure all vehicles and machinery are fitted with appropriate emission control equipment, maintained frequently and serviced to the manufacturer's specifications. • Smoke from internal combustion engines should not be visible for more than ten seconds.

7.2 Air Monitoring Programmes

As shown in **Section 9**, ambient air quality monitoring is currently being performed by DES in the area surrounding the SGP. Given that the downwind concentrations of NO_2 and CO predicted in this assessment are far below ambient air quality guidelines, no additional ambient monitoring is recommended for the FCS or well pad operations assessed in this AQIA.

Based on DES's streamlined conditions for petroleum activities,fuel burning and combustion equipment included in this assessment that would warrant air emissions monitoring are the FCS power station engines[2]. Consistent with the emission rates modelled in this AQIA, the point source emission limits for NO_X presented in **Table 19** are proposed for assessing compliance.

The air dispersion modelling results showed that the potential for adverse impacts due to CO emissions is negligible, and as such, annual monitoring of CO is not considered necessary.

Table 19 Proposed Point Source Emission Limits for Girrahween FCS

Source	Minimum Release Height	Minimum Exit Velocity	NO_x as Nitrogen Dioxide	
			Maximum Concentration	Maximum Mass Emission Rate
	(m)	(m/s)	(mg/Nm^3)	(g/s)
Generator Stack 1	5	32	750	1.5
Generator Stack 2	5	32	750	1.5
Generator Stack 3	5	32	750	1.5
Generator Stack 4	5	32	750	1.5
Generator Stack 5	5	32	750	1.5
Generator Stack 6	5	32	750	1.5
Generator Stack 7	5	32	750	1.5
Generator Stack 7	5	32	750	1.5

7.3 Proposed Air Conditions

In line with the streamlined model conditions for petroleum activities, the recommended streamlined conditions for this development are provided by model conditions Air 1 to Air 3 as follows:

Venting and flaring

Air 1.

Unless venting is authorised under the *Petroleum and Gas (Production and Safety) Act 2004* or the *Petroleum Act 1923*, waste gas must be flared in a manner that complies with all of (Air 1(a)) and (Air 1(b)) and Air 1 (c)), or with (Air 1(d)):

(a) an automatic ignition system is used, and

(b) a flame is visible at all times while the waste gas is being flared, and

(c) there are no visible smoke emissions other than for a total period of no more than 5 minutes in any 2 hours, or

(d) it uses an enclosed flare.

Fuel burning and combustion facilities – authorised point sources

Air 2A.

A fuel burning or combustion facility must not be operated unless it is listed in **Protecting air values, Table 1–Authorised point sources**.

Air 2B.

If a fuel burning or combustion facility is listed in Protecting air values, Table 1—Authorised point sources, the fuel burning or combustion facility must be operated so that the releases to air do not exceed the limits specified in **Protecting air values, Table 1—Authorised point sources** at the specified release point reference.

Protecting air values, Table 1 – Authorised Point Sources

Resource Authority	Facility	Release Point Reference	Equipment Description	Minimum Release Height	Minimum Efflux Velocity	NO_x as Nitrogen Dioxide	
						Maximum Concentration	Maximum Mass Emission Rate
				(m)	(m/s)	(mg/Nm^3)	(g/s)
PL305	Girrahween FCS	A1	Generator Stack 1	5	32	750	1.5
		A2	Generator Stack 2	5	32	750	1.5
		A3	Generator Stack 3	5	32	750	1.5
		A4	Generator Stack 4	5	32	750	1.5
		A5	Generator Stack 5	5	32	750	1.5
		A6	Generator Stack 6	5	32	750	1.5
		A7	Generator Stack 7	5	32	750	1.5
		A8	Generator Stack 8	5	32	750	1.5

Point source air monitoring

Air 3.

Point source air monitoring for each fuel burning or combustion facility listed in **Protecting air values, Table 1—Authorised point sources** must:

(a) be undertaken once:

i. in the first three months after first commissioned, and then

ii. every year thereafter (for seven of eight listed release points)

(b) be carried out when the facility the subject of the sampling is operating under maximum operating conditions for the annual period; and

(c) demonstrate compliance with the limits listed in **Protecting air values, Table 1—Authorised point sources** at each release point reference.

8.0 Conclusions

An air quality impact assessment, including a detailed air dispersion modelling study, has been performed to assess potential air quality impacts from the proposed Girrahween FCS operation. Dispersion modelling was performed for both normal maximum operating conditions and for flaring events. Modelling was also performed for air emissions associated with multi well pad operations to confirm the required separation distances between well pads and sensitive receptors.

Based on the modelling results, the following conclusions have been drawn for the proposed Girrahween FCS:

- The modelling of NO_X and CO emissions from the proposed, Girrahween FCS showed that under normal maximum operating conditions (i.e. concurrent operation of seven power station generators at maximum load) these emissions have no potential to give any significant rise to ground level exceedances of the relevant ambient air quality criteria at surrounding sensitive receptors. The incremental impacts predicted by the modelling of CO emissions are negligible.
- The modelling of NO_X and CO emissions from maximum flaring events at the proposed, Girrahween FCS showed that maximum predicted cumulative NO_2 and CO concentrations at all nearby sensitive receptors would remain well below the relevant ambient air quality guidelines.
- Modelling results for the well pad generators showed that a separation distance of 200 m between the well pad and the sensitive receptors would be adequate (for air quality constraints) for all categories of well pads (single and multiwell pads).

Based on the above, no air quality constraints have been identified for these facilities as a result of this air quality impact assessment.

Mitigation and monitoring measures are presented in this report to minimise emissions to air and assist in the management of air quality impacts associated with these facilities.

9.0 References

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Appendix A Isopleths

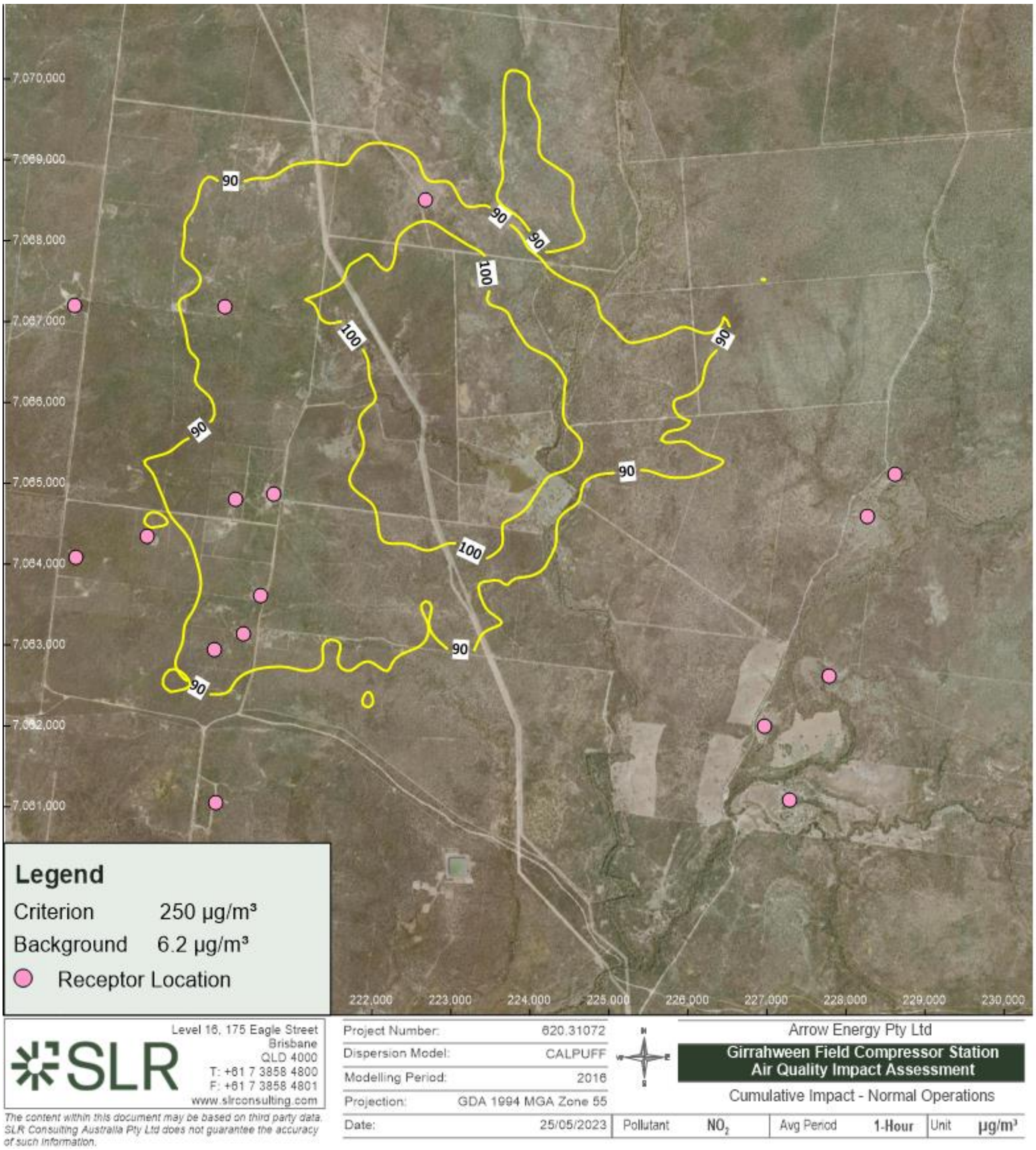
Surat Gas Project – Girrahween Field Compressor Station

Air Quality Impact Assessment

Arrow Energy Pty Ltd

SLR Project No.: 620.12248.01600

27 June 2023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Background 6.2 µg/m³
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Level 16, 175 Eagle Street
Brisbane
QLD 4000
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www.slrconsulting.com
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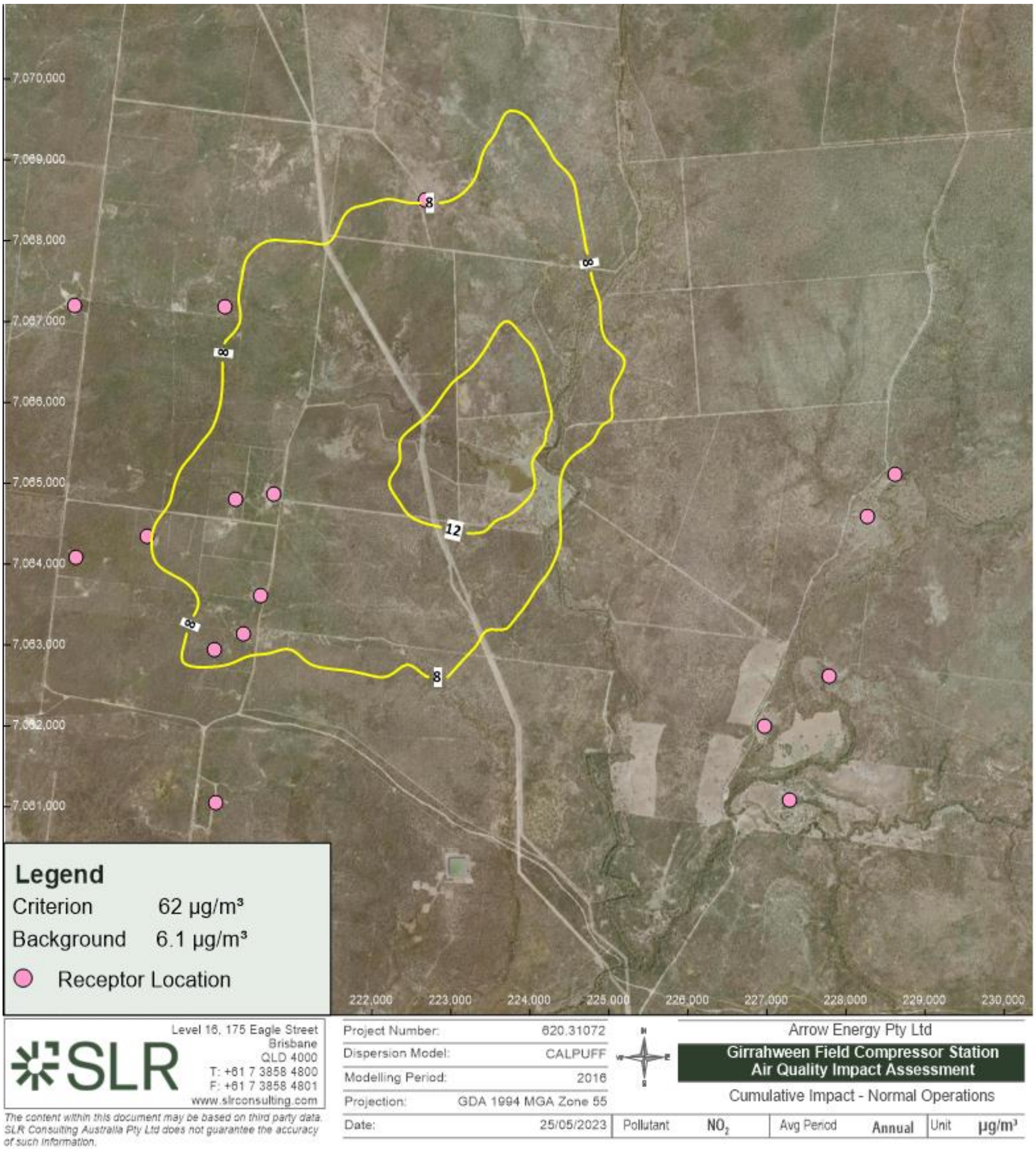
Project Number: 620.31072
Dispersion Model: CALPUFF
Modelling Period: 2016
Projection: GDA 1994 MGA Zone 55
Date: 25/05/2023
Arrow Energy Pty Ltd
Girrahween Field Compressor Station
Air Quality Impact Assessment
Cumulative Impact - Normal Operations
Pollutant NO₂
Avg Period 1-Hour
Unit µg/m³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Background 6.1 µg/m³
Receptor Location
SLR
Level 16, 175 Eagle Street
Brisbane
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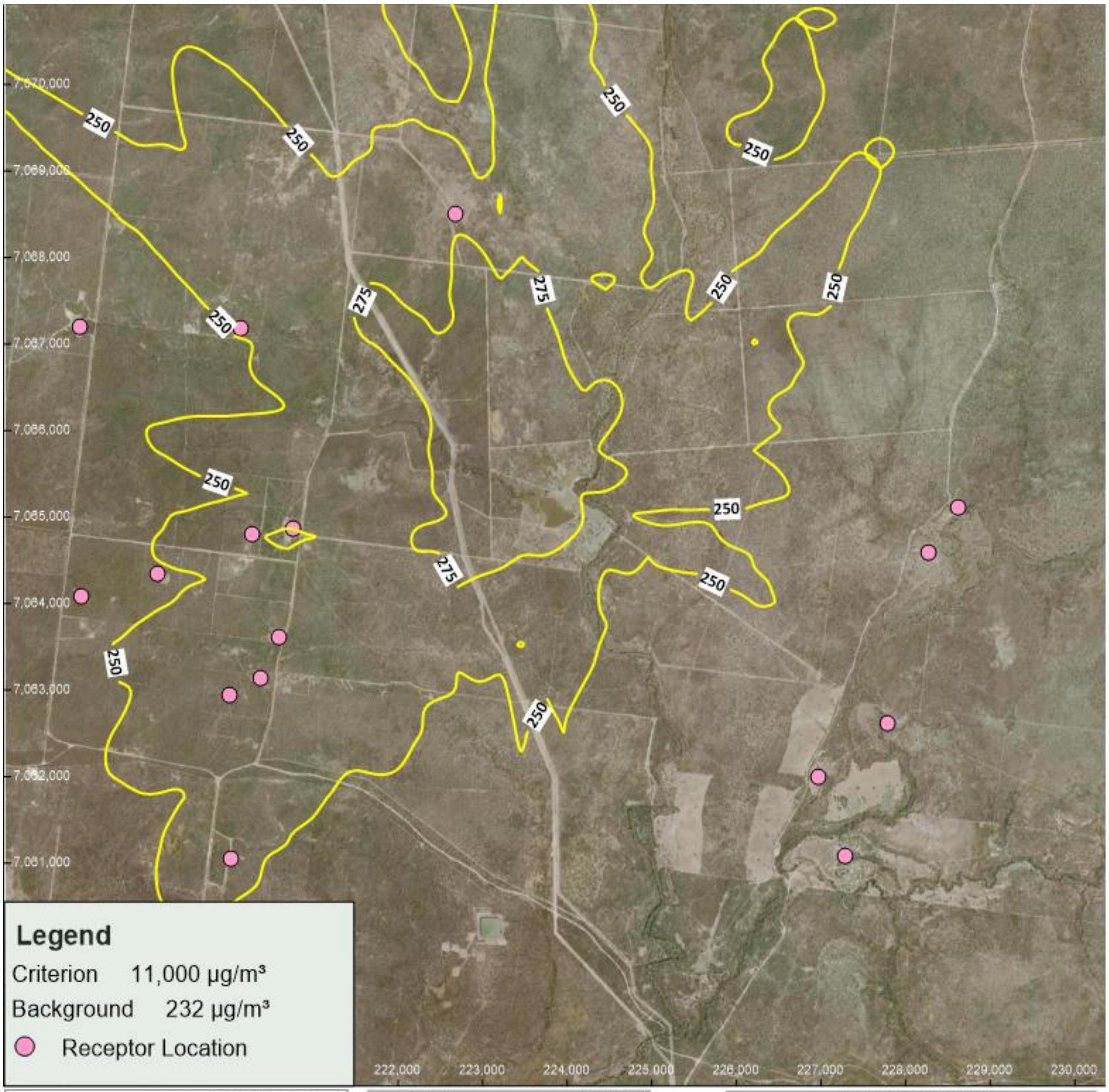
Projection: GDA 1994 MGA Zone 55
Date: 25/05/2023
Arrow Energy Pty Ltd
Girrahween Field Compressor Station
Air Quality Impact Assessment
Cumulative Impact - Normal Operations
Pollutant NO2
Avg Period Annual
Unit µg/m³



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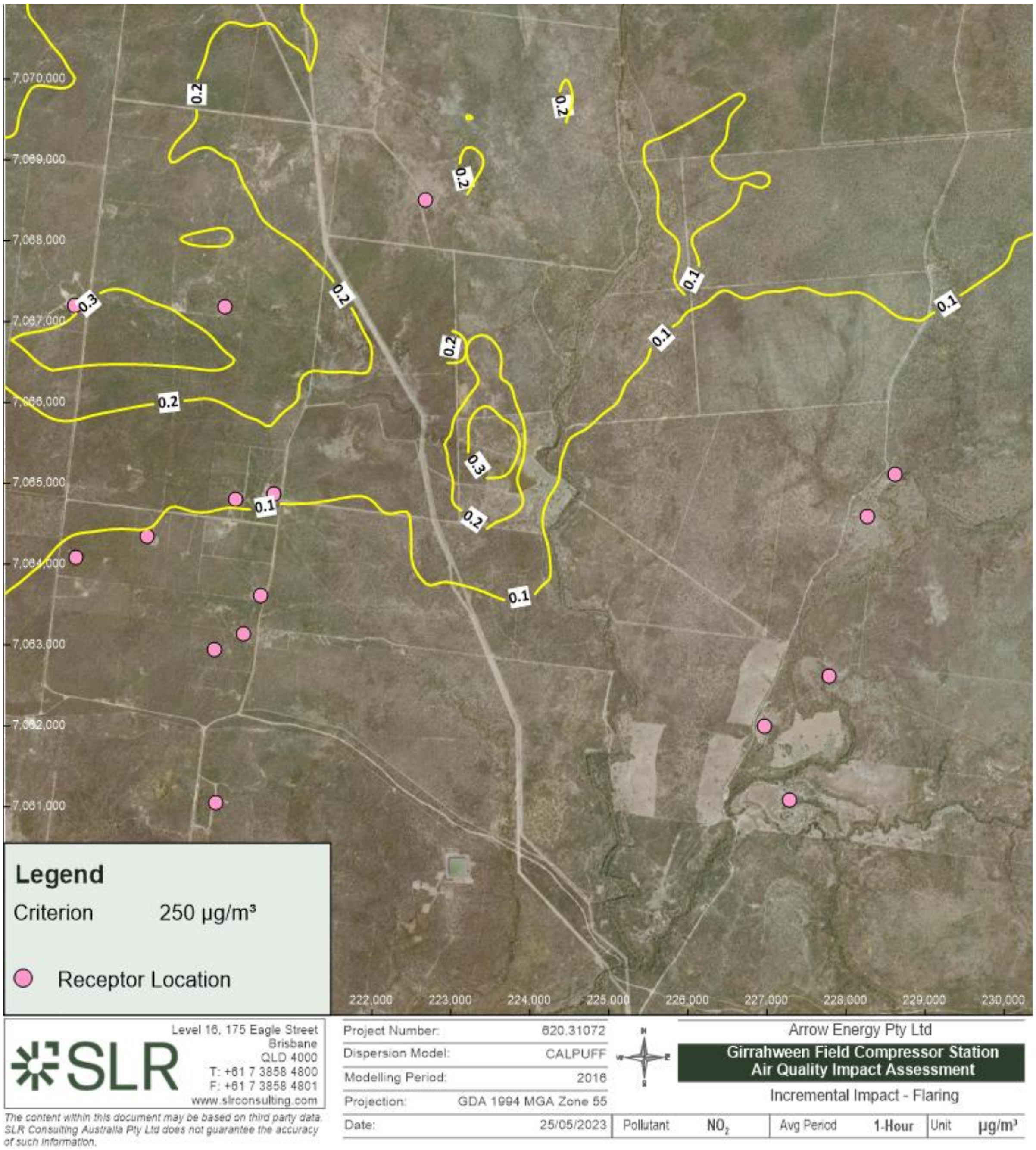
Date:	25/05/2023

Arrow Energy Pty Ltd

Girrahween Field Compressor Station
Air Quality Impact Assessment

Cumulative Impact - Normal Operations

Pollutant	CO	Avg Period	8-Hour	Unit	µg/m³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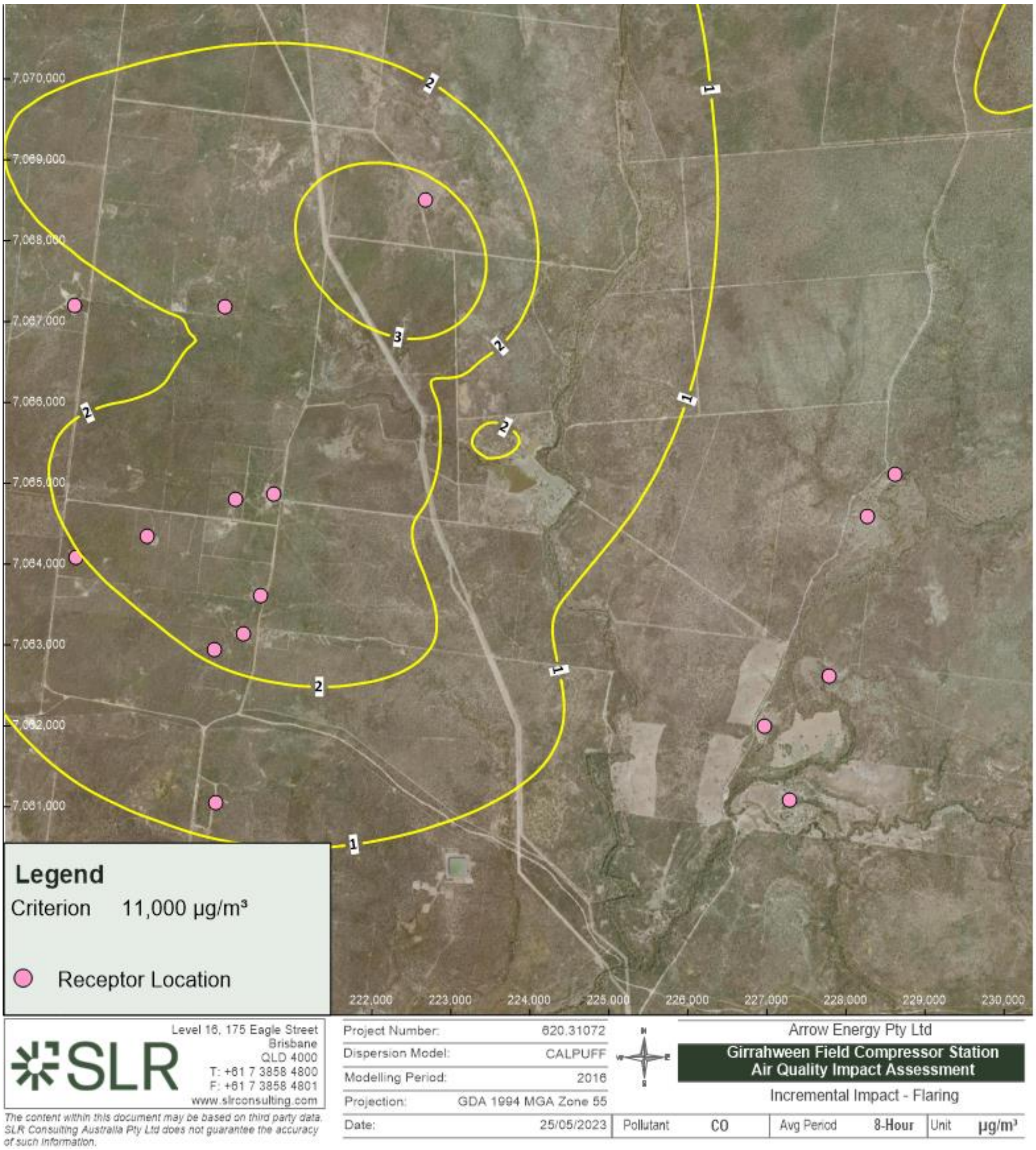
Modelling Period: 2016
Projection: GDA 1994 MGA Zone 55
Date: 25/05/2023
Arrow Energy Pty Ltd
Girrahween Field Compressor Station
Air Quality Impact Assessment
Incremental Impact - Flaring
Pollutant NO_2
Avg Period 1-Hour
Unit µg/m³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Criterion 11,000 µg/m³
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Incremental Impact - Flaring
Pollutant CO
Avg Period 8-Hour
Unit µg/m³

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